

AD-A157 319

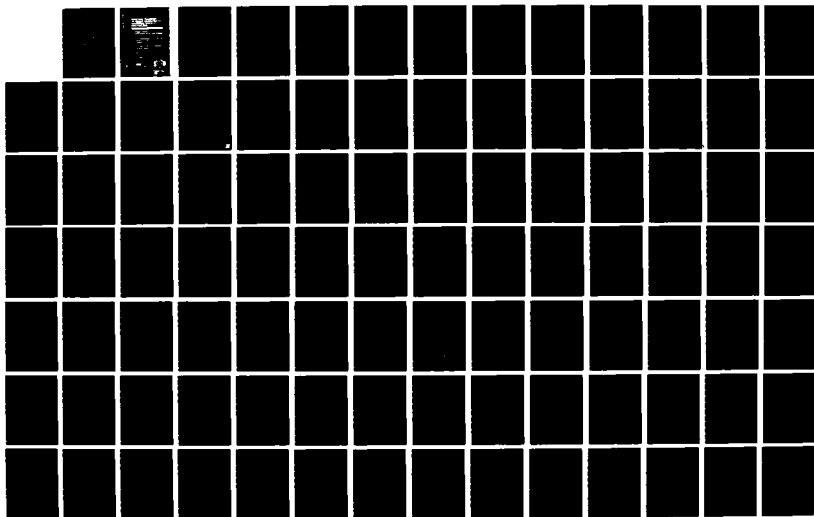
INDUSTRIAL PROCESSES TO REDUCE GENERATION OF HAZARDOUS
WASTE AT DOD FACIL. (U) CH2M HILL INC GAINESVILLE FL
T E HIGGINS 15 FEB 85 WDR-93/02 DACA87-84-C-0076

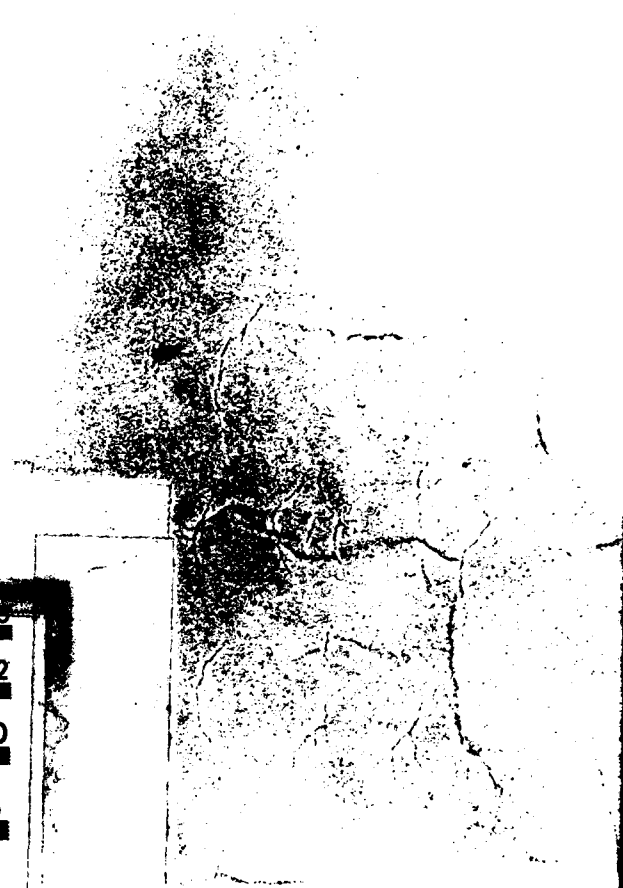
1/2

UNCLASSIFIED

F/G 13/2

NL





15

AD-A157 319

①

INDUSTRIAL PROCESSES TO REDUCE GENERATION OF HAZARDOUS WASTE AT DOD FACILITIES

PHASE I REPORT EVALUATION OF 40 CASE STUDIES

prepared for the
DOD ENVIRONMENTAL LEADERSHIP
PROJECT OFFICE
Washington, D.C.

and
U.S. ARMY CORPS OF ENGINEERS
Huntsville, Alabama

contract
DAC A87-84-C-0076

author
T.E. Higgins

DTIC FILE COPY

CHM HILL
February 1985

DTIC
ELECTE
JUL 23 1985
S D
* G

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS NONE		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) WDR 93/02			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION CH2M-HILL		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION DEFENSE ENVIRONMENTAL LEADERSHIP PROJECT		
6c. ADDRESS (City, State and ZIP Code) 1941 Roland Clarke Place Reston, VA 22091			7b. ADDRESS (City, State and ZIP Code) 1717 H Street, NW, Room 202 Washington, DC 20006-3901		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army C.O.E.		8b. OFFICE SYMBOL (If applicable) HNDED	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAC A87-84-C-0076		
8c. ADDRESS (City, State and ZIP Code) P.O. Box 1600 Huntsville, AL 35807-4301			10. SOURCE OF FUNDING NOS.		
			PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.
11. TITLE (Include Security Classification) INDUST. PROCESSES TO REDUCE GENERATION OF HAZ WASTE AT DOD FAC-UNCL					
12. PERSONAL AUTHOR(S) T. E. HIGGINS					
13a. TYPE OF REPORT FINAL		13b. TIME COVERED FROM 8/84 TO 2/85		14. DATE OF REPORT (Yr., Mo., Day) 1985 FEB 15	
15. PAGE COUNT 120					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) HAZARDOUS WASTE REDUCTION INDUSTRIAL PROCESS WASTE GENERATION RESOURCE CONSERVATION AND RECOVERY ACT		
FIELD	GROUP	SUB. GR.			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report is part of a Defense Environmental Leadership Project aimed at encouraging the development and implementation of industrial process modifications in U.S. Army, Navy, and Air Force facilities and, thus, at reducing the amount of hazardous wastes generated by those facilities. The report, which covers the first phase of the project, evaluates 40 case studies of industrial process modifications, and recommends 18 for further evaluation. Many studies of DoD facilities have recommended industrial process modifications that would reduce wastes generated at the source, rather than concentrating efforts on end-of-pipe treatment facilities. Some of these studies, which included many featuring excellent cost/benefit ratios, have been successfully implemented; some, however, have not. Therefore, the methods, such as incentives, and management practices used to successfully implement a given modification, are important factors in the evaluations of the case studies examined in this report. The case studies also were evaluated on the basis of technical practicality, cost, energy consumption, and program monitoring and auditing.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input type="checkbox"/>			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL ANDRES TALTS			22b. TELEPHONE NUMBER (Include Area Code) (202)-653-1273		22c. OFFICE SYMBOL DELP

NOTICE

This report has been prepared for the US Department of Defense by CH2M HILL for the purpose of reducing hazardous waste generation from DOD industrial processes. It is not an endorsement of any product. The views expressed herein are those of the contractor and do not necessarily reflect the official views of the publishing agency, or the Department of Defense.

Copies of this report may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia, 22161

Federal Government agencies and their contractors registered with Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center
Cameron Station
Alexandria, Virginia 22314

This report was prepared by CH2M HILL, Inc., Reston, Virginia, under Contract Number DAC A87-84-C-0076, August 17, 1984, for the Defense Environmental Leadership Project Office (DELPO) and the US Army Corps of Engineers (COE). Dr. Richard Boubel was the Project Officer for DELPO and Mr. Stan Lee was the COE Project Officer. Dr. Thomas E. Higgins was Project Manager for CH2M HILL and was principal author. Major sections of this report were authored by R. Benson Fergus, Drew P. Desher, and Daniel Bostrum of CH2M HILL.

WDR93/02

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input checked="" type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A/1	



EXECUTIVE SUMMARY

This report is part of a three-phase Defense Environmental Leadership Project aimed at encouraging the development and implementation of industrial process modifications in U.S. Army, Navy, and Air Force facilities and, thus, at reducing the amount of hazardous wastes generated by those facilities.

The report, which covers the first phase of the project, evaluates 40 case studies of industrial process modifications, and recommends 18 for further evaluation in Phase 2 of the project. From these 18 case studies, three will be selected as "Projects of Excellence" that will be promoted during Phase 3 to encourage similar efforts elsewhere in the armed services. Table 13.1 lists all cases, indicates those recommended for further study, designates whether the cases were technically successful, and notes the report section in which a given case is discussed.

The project is in keeping with Department of Defense (DOD) policy memorandum DEQPPM 80-5, issued in May of 1980 and reaffirmed in August of 1980 by policy memorandum DEQPPM 80-8. That policy essentially is to limit hazardous wastes generated by the U.S. Army, Air Force, and Navy through alternative procurement and operating procedures and, where possible, to reuse, reclaim, or recycle resources in order to conserve raw materials. Many studies of DOD facilities have recommended industrial process modifications that would reduce wastes generated at the source, rather than concentrating efforts on end-of-pipe treatment facilities. Some of these studies, which included many featuring excellent cost/benefit ratios, have been successfully implemented; some, however, have not. Therefore, the methods, such as incentives, and management practices used to successfully implement a given modification, are important factors in the evaluations of the case studies examined in this report. The case studies also were evaluated on the basis of technical practicality, cost, energy consumption, and program monitoring and auditing.

The contract instructed that the project should concentrate on a few processes that generate the greatest proportion of DOD hazardous wastes. The project did that by focusing on facilities involved in painting, paint stripping, metal plating, and the recycle of solvents and other organic fluids.

As for the 18 cases recommended for further study, 7 involved modifications to metal plating, 5 involved painting or paint stripping, 5 involved recovering solvents, and one involved changes in purchase and use specifications

to reduce disposal of items whose shelf life has expired. Other categories studied, but not yielding any cases recommended for further evaluation, were explosives manufacturing, jet engine test cell, fire fighting training, and fuel tank cleaning.

Those 18 cases are distributed throughout the Army, Air Force, and Navy in proportions comparable to the distribution of the original 40 cases. As for technological success, the 18 cases included 13 modifications that were successful and 5 that were not.

WDR93/02

7011-1-73

CONTENTS:

	<u>Page</u>
Executive Summary	i
1 INTRODUCTION	1-1
1.1 Background	1-1
1.2 Project Objectives	1-1
1.3 Evaluation and Further Study	1-2
1.4 Sources of the Cases Studied	1-2
2 SCOPE OF WORK	2-1
3 PAINT STRIPPING	3-1
3.1 Process Description	3-1
3.2 Magnitude of Problem	3-1
3.3 Proposed Modifications	3-1
3.4 Case Studies	3-4
3.4.1 Plastic Media Stripping, Hill AFB, Case No. 1	3-4
3.4.2 Dry Media Paint Stripping, Alameda NARF, Case No. 22	3-5
3.4.3 Dry Media Paint Stripping, Pensacola NARF Case No. 26	3-5
3.4.4 Wet Paint Stripping, Anniston Army Depot, Case No. 27	3-6
3.5 References	3-7
4 PAINTING	4-1
4.1 Process Description	4-1
4.2 Magnitude of Problem	4-1
4.3 Proposed Modifications	4-1
4.4 Case Studies	4-4
4.4.1 Electronic Dry Powder Painting, Hughes Missile Division, Case No. 3	4-4
4.4.2 Spray Painting, Lockheed-Georgia Company, Case No. 3	4-5
4.4.3 Painting Modification at Naval Air Rework Facilities (NARF's), Case No.s 27, 28, 34	4-7
4.5 References	4-9
5 METAL PLATING	5-1
5.1 Process Description	5-1
5.2 Magnitude of Problem	5-2
5.3 Proposed Modifications	5-4
5.4 Case Studies	5-6
5.4.1 Cadmium Plating at Lockheed, Case No. 6	5-6
5.4.2 LICON Chromium Recovery at Pensacola NARF, Case No. 9	5-7

CONTENTS (continued)

	<u>Page</u>
5.4.3 LICON Chromium Recovery at Charleston NYS, Case No. 12	5-9
5.4.4 Innovative Chromium Plating at Pensacola NARF, Case No. 10	5-10
5.4.5 Steam Condensate Recovery at Pensacola NARF, Case No. 11	5-12
5.4.6 Metal Sulfide Precipitation at Tobyhanna Army Ammunition Plant, Case No. 16	5-12
5.4.7 Plating at Anniston Army Depot, Case No. 18	5-15
5.4.8 Segregation of Chromium and Cyanide Rinsewater and Addition of More Rinse Tanks at Alameda NARF, Case No. 19	5-17
5.4.9 Conversion to Countercurrent and Conductivity Controlled Rinse at Alameda NARF, Case No. 20	5-19
5.4.10 Modern Plating System at Watervliet Army Arsenal, Case No. 23	5-19
5.4.11 Rinse and Bath Changes at Mare Island NSY, Case No. 31	5-19
5.4.12 Water Layer Over Methylene Chloride Tanks at Various NARF's, Case No. 32	5-20
5.4.13 Ion Vapor Deposition of Aluminum to Replace Cadmium Plating at Pensacola NARF and North Island Narf, Case No. 33	5-20
5.5 References	5-21
6 RECYCLE OF SOLVENTS & OTHER ORGANIC FLUIDS	6-1
6.1 Process Description	6-1
6.2 Magnitude of Problem	6-1
6.3 Proposed Modifications	6-2
6.4 Case Studies	6-6
6.4.1 Solvent Recycle at Warner Robins AFB, Case No. 4	6-6
6.4.2 Solvent Recycle at Tyndall AFB, Case No. 5	6-9
6.4.3 Heptane Recovery at Norfolk NARF, Case No. 7	6-11
6.4.4 Solvent Recovery at Norfolk NSY, Case No. 8	6-12
6.4.5 Solvent Recovery at Kelly AFB, Case No. 24	6-14

CONTENTS (continued)

	<u>Page</u>
6.4.6 Solvent Recovery at Pensacola NARF, Case No. 29	6-15
6.4.7 Refrigerant Reuse at Charleston NSY, Case No. 36	6-16
6.4.8 Refrigerant Reuse at Norfolk NYS, Case No. 37	6-17
6.4.9 Recycle of TCE from Vapor Degreasers at Anniston Army Depot, Case No. 39	6-17
6.4.10 Machine Tool Coolant Recycle at Pensacola NARF, Case No. 30	6-19
6.5 References	6-20
7 EXPLOSIVES MANUFACTURING	7-1
7.1 Process Description	7-1
7.2 Magnitude of Problem	7-1
7.3 Proposed Modifications	7-2
7.4 Case Studies	7-3
7.4.1 Molecular Sieves At Radford Army Ammunition Plant, Case No. 13	7-3
7.4.2 Molecular Sieves at Holston Army Ammunition Plant	7-5
7.4.3 Carbon Adsorption at Radford Army Ammunition Plant, Case No. 14	7-7
7.4.4 Internal Water Recycle at Milan Army Ammunition Plant, Case No. 15	7-8
7.5 References	7-9
8 JET ENGINE TEST CELL	8-1
8.1 Process Description	8-1
8.2 Magnitude of Problem	8-1
8.3 Proposed Modifications	8-1
8.4 Case Studies	8-2
8.4.1 Conversion from Wet to Dry System at Alameda and North Island NARF's, Case No. 21	8-2
9 FIRE FIGHTING TRAINING	9-1
9.1 Process Description	9-1
9.2 Magnitude of Problem	9-1
9.3 Proposed Modifications	9-1
9.4 Case Study	9-3
9.4.1 Replacement of AFF with Ultrawet K at Norfolk Naval Air Station, Case No. 35	9-3
9.5 References	9-3

CONTENTS (continued)

	<u>Page</u>
10 FUEL TANK CLEANING	10-1
10.1 Process Description	10-2
10.2 Magnitude of Problem	10-2
10.3 Proposed Modifications	10-4
10.4 Case Studies	10-4
10.4.1 Craney Island and Yorktown Fuel Farms, Case No. 38	10-4
10.5 References	10-5
11 PURCHASE AND USE SPECIFICATIONS	11-1
11.1 Process Description	11-1
11.2 Magnitude of Problem	11-2
11.3 Proposed Modifications	11-2
11.4 Case Studies	11-3
11.4.1 NYS and NARF, Norfolk, Virginia, Case No. 40	11-3
11.5 References	11-4
12 SUMMARY AND CONCLUSIONS	12-1
12.1 Features of Successful Modifications	12-1
12.2 Evaluation Results	12-2
12.2.1 Paint Stripping	12-2
12.2.2 Painting	12-3
12.2.3 Metal Plating	12-3
12.2.4 Recycle of Solvents and Other Organic Fluids	12-4
12.2.5 Explosives Manufacturing	12-5
12.2.6 Jet Engine Test Cell	12-5
12.2.7 Fire Fighting Training	12-5
12.2.8 Fuel Tank Cleaning	12-6
12.2.9 Purchase and Use Specifications	12-6
13 RECOMMENDATIONS	13-1
13.1 Evaluation and Recommendation of Cases	13-1
13.2 Distribution of Recommended Cases	13-3

WDR93/02

TABLES

		<u>Page</u>
1.1	Summary of Case Study Evaluations	1-5
13.1	Evaluation of Case Studies	13-4

WDR93/02

Introduction

.. INTRODUCTION

..1 Background

In May of 1980, the Department of Defense (DOD) issued policy memorandum DEQPPM 80-5, which assigned the individual armed services with the responsibility to "where feasible, minimize quantities of hazardous wastes, through resource recovery, recycling, source separation, and acquisition policies." In August of 1980, DOD policy memorandum DEQPPM 80-8 affirmed that DOD policy is:

. . . to limit the generation of hazardous waste through alternative procurement and operational procedures that are attractive environmentally yet are fiscally competitive, (and) . . . to reutilize, reclaim, or recycle resources where practical and thus conserve on total raw material usage.

In carrying out the intent of these policies, numerous studies have been performed at DOD facilities which recommended modifications to industrial processes to reduce the generation of hazardous wastes at the source, rather than treating the wastes at end-of-pipe treatment facilities. Many of these studies recommended process modifications with excellent cost/benefit ratios. Several of these have been successfully implemented. However, others have either not been implemented or were improperly applied.

1.2 Project Objectives

This report is part of Phase 1 of a three-phase Defense Environmental Leadership Project, which is aimed at accomplishing the intent of the above-noted DOD policies. This project is intended to encourage the development and implementation of industrial process modifications that will reduce the amount of hazardous waste generated by the U.S. Army, Navy, and Air Force.

The three phases of the project are:

- o Phase 1: Evaluate 40 cases of industrial process modifications, taken from the Army, Navy, and Air Force, and recommend 18 of those cases for further study during Phase 2. The primary factor in evaluating the cases was not whether they had been successful, but rather whether they were useful as examples of how such processes could be implemented.

Many times, the success or lack of success of the modification can be attributed not to the technology, but rather to the management, training,

correct plastic beads and operating parameters for a given fiberglass resin. With hard epoxy resins, the plastic media blasting works quite well. However, with fiberglass which contains polyester resins, it is very easy to damage the fiberglass with the plastic media. Unfortunately, the type of plastic media that should be used cannot be predetermined by visual inspection. Though extreme care must be taken using this method, Pensacola personnel feel that they have developed their technique to the point where this is a minor problem. Besides reducing hazardous waste generation, dry media blasting has produced additional benefits. For example, this method allows them to strip parts, such as helicopter floorboards, which could not be stripped by either wet solvent or grinding methods. In addition, the plastic media stripping does a clean and complete job - whereas chemical stripping almost always leaves some residue to be hand sanded or ground off.

A program has been set up where every new part or material which comes into the NARF requiring stripping is tested with plastic media blasting. Their ultimate goal is complete conversion to dry media stripping. However, some parts or materials may require solvents to perform the initial stripping followed by plastic media blasting for final paint removal.

At the time of this writing, Pensacola has temporarily discontinued the proposed renovation of the hangers for dry media paint stripping. OSHA was concerned that the dust generated from stripping operations would pose an explosion hazard. One regulation implies that people cannot work in an enclosed area where paint stripping is being done with "organic" media. The regulations were written because of dusting problems associated with stripping paint with vegetable organics such as walnut shells. It is unclear if plastic media is considered an organic material. Another conflicting regulation allows paint stripping with dry media as long as the air flow and dust level are monitored. The Department of Labor is currently reviewing the regulations and will determine which provisions apply. Pensacola personnel believe that plastic media paint stripping will be allowed as long as adequate measures are taken to minimize any possible hazard. Until a final decision is reached, Pensacola will continue to paint strip with plastic media in enclosed glove boxes and walk-in blast rooms.

3.4.4 Wet Paint Stripping, Anniston Army Depot Case No. 17

Anniston Army Depot is a government-owned, government-operated facility in Anniston, Alabama. At this facility, approximately 700 tanks are reconditioned each year.

The process also appears to be less labor intensive and occupationally less hazardous than solvent stripping. In addition, greater control in stripping has been achieved, resulting in reduced damage to underlying surfaces. The use of plastic beads instead of other media (walnut shells, rice hulls, etc.) reduces dust generation (and the accompanying explosion hazard) and avoids potential problems with biological growth in the media.

This dry media paint stripping techniques was championed by Mr. Bob Roberts, who personally developed and promoted the process. Motivated by the anticipated environmental restrictions on the continued use of solvent stripping, he tested various natural blasting media before settling on the plastic beads. He has developed a live floor vacuum system to provide ventilation for bead and dust removal, and a separation system for bead recovery reuse (2). Due to the method's promise of reduced manpower requirements and favorable environmental impact, a full size demonstration bead blasting hanger is being constructed using special funding that allowed "fast track" construction procedures. The hanger incorporates the live recovery floor and will be capable of stripping whole airplanes.

3.4.2 Dry Media Paint Stripping, Alameda NARF Case No. 22

A study similar to that performed at Hill AFB was thought to be undertaken at Alameda Naval Air Rework Facility (NARF). However, Mr. Leroy Rogers, Paint Supervisor of Alameda NARF, indicated that they have not yet tried dry media stripping, opting instead to wait for results from Hill AFB. Conventional solvent stripping is still used at this facility.

3.4.3 Dry Media Paint Stripping, Pensacola NARF Case No. 26

The NARF at Pensacola reconditions both aircraft and helicopters. Wet paint stripping is the most common technique used for paint stripping from aircraft at this site. Because of the fiberglass present in most helicopters, however, solvent stripping cannot be used (the solvents tend to dissolve the fiberglass resins). Consequently, sanding and grinding are used to remove helicopter paint. The method is laborious and requires skilled technicians.

Currently four hangers are used for helicopter paint stripping. Pensacola plans to convert two of these hangers to accommodate dry media stripping. Plastic media paint stripping is currently being performed in enclosed glove boxes and walk-in blast rooms. Plastic media blasting has been quite successful in helicopter stripping, despite some difficulties. The main problem has been choosing the

However, because of the potential for tremendous reduction in hazardous waste generation, this method too is in the testing phase. Mr. Mike Halliwell, Wright Patterson Air Force Base, believes that flash lamp and laser stripping have equal probabilities for success.

Water Jet Stripping is the use of water under high pressure to remove paint. This method has been tried but discontinued because the high water pressure required caused damage to some aircraft surfaces. The method was used successfully for paint removal from a landing gear, but has not been permanently implemented.

CO₂ Pellet Stripping, which involves stripping by blasting with pellets of CO₂. The high pressure required to strip paint from aircraft was greater than that allowed for aircraft skin surfaces (2). An advantage of this process, making it warrant further research, is that the carbon dioxide vaporizes and thus does not contribute to hazardous waste generation.

Cryogenics, or removal of paint by freezing in liquid nitrogen and physically "knocking" the paint off, has been tried but is not yet workable or cost effective. In addition, the process required total immersion in liquid nitrogen, which limits application to smaller parts (although there is some work being done in which liquid nitrogen is poured over entire aircraft). However, the effect of extremely cold temperatures on aircraft electronics, rivets, bolts, etc., is not yet known.

3.4 Case Studies

3.4.1 Plastic Media Paint Stripping, Hill AFB Case No. 1

Current methods for aircraft paint stripping at Hill Air Force Base, Ogden, Utah, use an acidic methylene chloride solution to dissolve and loosen the paint. The paint/solvent mixture is scraped from the aircraft and washed down with approximately 20,000 gallons of water per plane which is discharged to the industrial waste treatment plant.

Plastic media paint stripping, one of the most promising alternatives to conventional solvent stripping, has been successfully demonstrated for aircraft renovation at Hill AFB. In this process, old paint is removed with conventional sand blasting equipment using recoverable plastic beads in lieu of sand. A dry waste of pulverized paint and plastic beads is produced. Waste volume is significantly reduced and more readily disposed of than the wastewater produced in conventional solvent stripping.

type of resin which is present usually cannot be pre-identified. Damage to the fiberglass surface is probable if the wrong media or method is used to strip the coating.

OSHA has been concerned that the dust generated from plastic bead stripping operations would pose an explosion hazard. Regulations imply that people cannot work in an enclosed area where paint stripping is being done with "organic" blasting media. These regulations were written because of dusting problems associated with stripping paint with vegetable materials such as walnut shells. It is unclear if plastic media is considered an organic material. Another conflicting regulation allows paint stripping with dry media as long as the air flow and dust level are monitored. The Department of Labor is currently reviewing these regulations and will determine which provisions apply.

Solvent Reuse techniques have been investigated to prolong the life of paint stripping solvents and hence minimize the use, and waste, of fresh solvents. Successful solvent recycle has been demonstrated in the laboratory by using pressure filtration. Though not implemented, an estimate at Ogden Air Force Base indicates that over \$60,000/month could be saved if a full solvent reuse program were put in place (3).

Some of the more exotic alternatives to conventional solvent stripping include:

Laser Paint Stripping, in which tests were conducted using a pulse CO₂ laser. When an infrared frequency laser beam was used to vaporize (presumably to CO₂ and H₂O) paint from a test surface, there was virtually no material residue left and hazardous waste generation was eliminated. The laser was not effective in removing pore deposits, and there is a potential problem with damage to aircraft electronics. There is also some concern about flammability with laser stripping. Though inexpensive to operate, the laser is quite expensive to purchase, requires robotic control to obtain the necessary precision and is extremely complicated to operate and maintain, requiring highly skilled operators. Though promising, this technique for hazardous waste reduction is still in the testing stages. It has not yet been implemented in place of conventional solvent stripping at any DOD site.

Flash Lamp Stripping is similar to stripping with laser light, but uses high energy quartz lamps to vaporize paint. Unlike laser stripping, flash lamps will not harm aircraft electronics. However, this technique is difficult to operate, requiring extensive operator training. In Navy tests, this method failed to remove barnacles from the bottom of ships, and produced loud, annoying "bangs" when operating.

however, are quite promising for both economics and quality of results.

In plastic media stripping, small, rough edge plastic beads are air blasted at the painted surface literally causing the coating to dislodge. By carefully controlling the size of the beads and the conditions of the process, the plastic media can be separated from the loosened paint particles and recycled. Generation of wet hazardous waste (solvents and paint sludge in water) is completely eliminated. A small volume of dry waste is produced, which would be classified as hazardous due to metal content.

The key parameter for successful use of plastic media blasting is hardness - the paint must be softer than the plastic media, which in turn must be softer than the surface underneath the paint coat. Unfortunately, for a great many military paint stripping applications, this relation does not hold. With epoxy and urethane paints on aluminum surfaces, for example, the paint is harder than the surface and dry blasting is not applicable. This problem has been alleviated by presoftening the paint with a stripping solvent, such as methylene chloride, and then allowing the paint to dry prior to blasting. A high degree of success has been attained by using this technique.

Currently only United States Plastic and Chemical Company, a former subsidiary of Koppers, Inc., manufactures the plastic beads. The plastic media comes in three different materials (Polyextra, Polyplus, and a proprietary material called Type 3) and six different grain size sieve distributions (12-16, 16-20, 20-30, 30-40, 40-60, 60-80). Since there is only one supplier of the plastic beads, some people have expressed a concern with totally relying on plastic media paint stripping because of possible future shortages and exorbitant price hikes.

Mechanical problems with plastic media stripping have included excessive dust generation, dust penetration into surface pores, and dust penetration into bearings and engines. In addition, many newer aircraft use honeycomb structures and thin skins which are not readily amenable to blasting techniques.

The operators of plastic media stripping equipment must be highly skilled to avoid damaging the underlying surface from which paint is being stripped. In fact, many experts in the field believe the greatest drawback to this technique is the difficulty in setting and controlling the myriad of variables for each application (bead hardness, roughness and size, motive air pressure, standoff distance, application angle, nozzle size, feed rate, etc.). This task is especially difficult with fiberglass resin surfaces since the

3. PAINT STRIPPING

3.1 Process Description

Paint stripping is the process of removing paint and coatings from surfaces in preparation for recoating. Complete stripping is often necessary for new paint and coatings to properly adhere to existing surfaces. In typical military paint stripping, sprays or baths containing acidic methylene chloride solutions, phenolic solutions, or hot alkaline sodium hydroxide solutions are employed to dissolve and loosen old paint. After scraping, the resulting solvent-paint mixture is washed away with large volumes of water, resulting in significant quantities of hazardous waste. The process is labor intensive, dirty, and may overload waste treatment facilities.

3.2 Magnitude of Problem

Paint stripping operations are performed at virtually every industrial facility throughout the DOD, spanning all military services across the United States. To illustrate the magnitude of hazardous waste generation, previous studies have estimated that each naval shipyard generates about 9,000 gallons of paint solvent waste each year (1). Approximately 20,000 gallons of solvent-laden wastewater is generated for each military aircraft repainted.

3.3 Proposed Modifications

Several alternative industrial and military processes for paint stripping have been studied. Among these are:

Dry Media Stripping is the removal of paint by blasting the surface with a dry media. Conventional sand blasting, abrasive blasting, and glass bead blasting have been extensively used for decades to remove paint and rust from metal surfaces. These paint removal techniques cannot be used in many military applications because the abrasive media can damage aluminum and fiberglass surfaces and small delicate steel parts. Sand and glass blasting can also cause deleterious respiratory ailments, such as silicosis. In many recent cases, a softer, more suitable dry media has successfully replaced sand and glass for various paint stripping operations. This "soft media" blasting method has received considerable attention for both military and industrial applications. Though the list of potential materials for use as dry media is virtually endless, only a few have gained popularity. Some of the more recent materials (walnut shells, rice hulls, etc.), are reasonably effective but are also susceptible to biological growth during storage and are difficult to recycle. Certain plastic media,

Paint Stripping

identify the process modifications which should have priority for further consideration.

This Phase 1 Report was prepared to fulfill the requirements of section 2.2.1.1 of the contract. The Scope of Work goes on to describe Phases 2 and 3 of the project. In Phase 2 the AE is charged to further investigate the 18 process modifications selected in Phase 1 for further study. In section 3.0 of the contract, entitled OBJECTIVES, it is further enumerated that of the 18 cases selected for analysis in Phase 2 of the project, approximately 9 were to have been successfully applied. The remaining cases were to be those that were not successfully applied.

At the end of Phase 2, three Projects of Excellence are to be identified for the development of employee training and briefing programs to be carried out in Phase 3 of the project.

WDR93/03

2. SCOPE OF WORK

Under the General Statement of Services in the contract under which this project was performed, the Architect-Engineer (CH2M HILL) is charged to:

- o Review and analyze existing studies on industrial process modifications to reduce the generation of hazardous wastes.
- o Identify techniques and the climate that are necessary for the modifications to be successful.
- o Develop programs to assure successful adoption of environmental control and hazardous waste reduction programs.

The Scope of Work applicable to Phase 1 of the project is detailed as follows:

- 2.1 The AE shall apply innovative approaches to this project as the basis for positive, action oriented results. The AE shall identify any R&D requirements for which there is a need. The study reports will include justification to support all recommendations.
- 2.2 The AE shall investigate and analyze industrial process modifications to reduce hazardous waste generation.
 - 2.2.1 The AE shall review and analyze 40 studies, by either the services themselves or previous contractors who have investigated the various industrial process modifications to reduce hazardous waste generation. The studies will include: (1) Industrial processes which were studied and found to be acceptable for modifications and then were successfully modified with the changes implemented and operated according to the plan proposed in the original study. (2) Industrial processes which were detailed and found to be acceptable for modification but which were not successfully modified with the changes implemented and operated according to the plan proposed in the original study.
 - 2.2.1.1 The AE shall prepare a report of the analysis performed on the 40 studies considering items such as costs, energy consumption, practicality, management, incentives, and program monitoring and auditing. This report shall stand alone and

Scope of Work

CASE NO.	FACILITY, MODIFICATION	STUDY VALUE	NOTES	REPORT SECTION
1	Hill AFB, Dry Paint Stripping	10.0	S *	3.4.1
4	Robins AFB, Solvent Recycle	10.0	S *	6.4.1
10	Pensacola NARF, Spray Rinse	10.0	S *	5.4.4
26	Pensacola NARF, Dry Paint Strip	10.0	S *	3.4.3
5	Tyndall AFB, Solvent Recycle	9.4	U *	6.4.2
18	Anniston Army Depot, Plating	9.4	S *	5.4.7
8	Norfolk NSY, Solvent Recycle	9.0	S *	6.4.4
24	Kelly AFB, Solvent Recycle	9.0	N	6.4.5
7	Norfolk NARF, Heptane Recycle	8.8	U *	6.4.3
22	Alameda NARF, Dry Paint Strip	8.6	N	3.4.2
23	Watervliet Army Arsenal, Modern Plating	8.4	S *	5.4.10
6	Lockheed (USAF), CD Plating	8.4	S *	5.4.1
16	Tobyhanna AAP, Waste Treatment	8.4	S *	5.4.6
27	Pensacola NARF, Water Primer	8.4	S *	4.4.3
39	Anniston Army Depot, Solvent Recycle	8.4	S *	6.4.9
33	NARF'S, IVD of Aluminum	8.2	S *	5.4.13
2	Hughes (USAF), Powder Coating	8.0	S *	4.4.1
3	Lockheed (USAF), Painting	8.0	U *	4.4.2
40	Norfolk NSY & NARF, Shelf Life	8.0	U *	11.4.1
12	Charleston NSY, Licon Unit	7.8	U *	5.4.3
9	Pensacola NARF, Licon Unit	7.8	U	5.4.2
14	Radford AAP, Pink Water	7.0	S	7.4.3
29	Pensacola NARF, Solvent Recycle	7.0	U	6.4.6
34	NAVY, Electrostatic Paint	6.4	U	4.4.3
30	Pensacola NARF, Machine Coolant	6.2	U	6.4.10
13	Radford AAP, NOX Control	5.6	U	7.4.1
15	Milan AAP, Pink Water	5.6	S	7.4.4
20	Alameda NARF, Rinse Controls	5.6	U	5.4.9
25	Holston AAP, NOX Treatment	5.6	U	7.4.2
38	NAVY, Fuel Tank Cleaning	5.6	U	10.4.1
28	Pensacola NARF, Epoxy Paint	5.2	U	4.4.3
31	Mare Island NSY, Plating	5.2	S	5.4.11
19	Alameda NARF, CN Rinse Changes	4.6	S	5.4.8
35	NAS'S, Fire Fighting	4.6	S	9.4.1
36	Charleston NSY, Refrigerant	4.2	S	6.4.7
17	Anniston Army Depot, Wet Paint Strip	4.0	N	3.4.4
21	NARF, Dry Jet Engine Test	3.6	S	8.4.1
32	NARF'S, Water Over MeC1	3.0	N	5.4.12
37	Norfolk NSY, Refrigerant Recycle	2.8	U	6.4.8
11	Pensacola NARF, Cond. Recovery	2.0	N	5.4.5

NOTES: S - Successful
U - Unsuccessful
N - Not sufficient information available
* - Recommended for further study in Phase 2

TABLE 1.1
SUMMARY OF CASE
STUDY EVALUATIONS

CHM HILL

These cases involved process modifications to reduce discharges of pink water and oxides of nitrogen from explosives manufacturing, conversion to dry jet engine test cells, a change in chemicals used for fire fighting training, changing the frequency of fuel tank cleaning and modifying purchase and use specifications to reduce the disposal of materials due to expired shelf life.

A description of the scope of work can be found in the next chapter of this report, followed by descriptions of the process modifications, conclusions, and finally, recommendations of 18 cases for further evaluation in Phase 2 of the project.

WDR93/05

The Department of Defense owns facilities for metal finishing, which is a predominant contributor to hazardous waste production at military facilities. Metal finishing can be performed on new parts as part of the manufacturing process, or as a means of repairing or remanufacturing equipment.

DOD metal finishing shops perform a variety of operations, including: paint and metal stripping, removal of dirt, oils, greases and corrosion products, metal plating, and painting. Each of these operations results in the production of wastes that must be handled and properly disposed of.

Modifications that were investigated to reduce waste generation from electroplating facilities included: metal recovery from rinsewaters, reduction of rinsewater volumes, plating bath cleanup techniques to reduce frequency of disposal, conversion from cyanide to noncyanide plating baths, and ion vapor deposition of aluminum in lieu of cadmium plating for corrosion protection.

Paint stripping is a major hazardous waste generator at DOD facilities. The case studies evaluated involved paint stripping of aircraft and parts. Typically, acidic methylene chloride or phenolic paint strippers are sprayed on the plane to dissolve the paint, which is then physically removed. The paint-solvent mixture generally falls to the floor beneath the plane and is washed into the facility's wastewater collection system.

Modifications investigated in Phase 1 include new mechanical and physical techniques for stripping the paint, laser stripping, and solvent reuse. The most promising technique was dry media blasting using a soft recoverable plastic media.

Painting modifications involved reduction in the use of volatile solvents, such as use of water-based primers, electrostatic painting and use of powder coating.

Most process modifications implemented to recover and reuse a portion of the solvents used involve the addition of distillation systems. Several types of distillation systems have been examined, including atmospheric stills, vacuum stills, indirectly heated stills, and stills using direct steam injection. Other solvents and organic fluids were recycled by unique, innovative treatment, and recovery processes.

In addition, cases involving explosives manufacture, jet engine test cells, fire fighting training, fuel tank cleaning, and purchase and use specifications were examined.

and incentive programs that were developed and put into place along with the technology. The report identifies managerial techniques that stimulate acceptance and successful implementation of the selected process modifications.

- o Phase 2: Further evaluate the 18 cases selected from Phase 1, and recommend 3 as "Projects of Excellence" to be promoted during the third and final phase of the project.
- o Phase 3: Promote the three "Projects of Excellence," using employee training and briefing programs to encourage the development and implementation of similar projects, and emphasize commitment to this project's ultimate goal, which is to reduce the generation of hazardous wastes.

1.3 Evaluation and Further Study

Table 1.1 lists the 40 case studies for Phase 1 and notes the cases recommended for further study, as well as the ranking given each case. A more detailed summary of the evaluations is shown in Table 13.1. Case studies were evaluated on the basis of costs, energy consumption, technical practicality, management, incentives, and program monitoring and auditing. The investigation of the 18 cases during Phase 2 will include an evaluation of the work environment which contributed to and resulted in the success, or lack of success, of the modification. Administrative, educational, and motivational programs will be considered as they relate to the success or lack of success for each case study.

1.4 Sources of the Cases Studied

Of the 40 cases examined in Phase 1, 32 represent three industrial processes which generate the greatest portion of DOD hazardous wastes (painting and paint stripping, electroplating, and solvent cleaning). Also, most of the cases of process modifications covered in this report occur either in manufacturing or in repair and reconditioning facilities.

Manufacturing usually is performed by civilian contractors operating government-owned, contractor-operated (GOCO) facilities, such as Air Force Plant 6, in which Lockheed manufactures and modifies cargo planes. To extend service life, military equipment is repaired at the point of use and periodically reconditioned at centralized facilities. The repair and reconditioning facilities are typically government-owned and government-operated (GOGO); the Anniston Army Depot, which is responsible for the reconditioning of armored vehicles, is one such facility.

After the tanks are completely disassembled, all reusable parts are stripped of their old paint layer before replating or repainting. The predominant method used for stripping is immersion in a wet chemical solution, though some small parts are sandblasted. Ferrous materials are stripped in hot alkaline sodium hydroxide baths while aluminum parts are stripped in solutions containing phenol, dichloromethane, and formic acid. Paint stripping baths are located in the components shop, engine shop transmission shop, and plating shop.

Solvent wastes are transported offsite for treatment or deep well injection, while solid paint wastes are drummed and shipped to Chemical Waste Management's secure landfill in Emelle, Alabama.

Since Anniston has not experienced any problems with these procedures, no modifications have been suggested or implemented to reduce the amount of hazardous waste produced.

3.5 References

- (1) Moore, Gardner and Associates, Naval Shipyards Industrial Process and Waste Management Investigation, U.S. Government contract N00025-80-C-0015, July 1983.
- (2) Roberts, R.A., Intermediate Report on Mechanical Coating-Removal Techniques, Hill Air Force Base, Ogden, Utah, 1984.
- (3) Walker, Maj. T.J., et al, "Getting Rid of Hazardous Wastes," The Military Engineer, October 1984.

WDR93/06

Painting

4. PAINTING

4.1 Process Description

Paint coatings are applied to surfaces of military parts, vehicles, and structures for corrosion protection and aesthetic appeal. In conventional liquid spray technology (by far the most common method for paint application in the military), paint is mixed with a solvent carrier and applied to surfaces in a wet form. Typically, low transfer efficiencies are realized--less than 50 percent of the paint solids consumed end up on the cured or dried part (1). Conventional spray painting is usually done in a horizontal or downdraft paint spray booth, or paint hanger for whole airplane painting. Paint overspray is scrubbed from the booth exhaust air by a water spray washer. Paint solids from the air scrubber sump are collected along with the waste solvents from cleanup processes for disposal as hazardous waste.

4.2 Magnitude of Problem

Painting is common to virtually all DOD facilities. Consequently, the waste disposal problems created by painting processes are significant. For example, a typical naval shipyard produces about 4,000 gallons per year of waste epoxy paint and 1,000 gallons per year of other waste paints. Disposal and replacement costs for the epoxy paint alone amounts to about \$100,000 per year (2). Naval aircraft are repainted yearly, while Air Force aircraft are repainted about every five years. The basis for requiring naval aircraft to be painted at an interval that is one fifth the interval for the Air Force may be worth investigating, although this is outside of the scope of this project. Nevertheless, with thousands of military aircraft in service, a significant volume of paint and paint solvents are consumed (and wasted) every year.

4.3 Proposed Modifications

Alternatives to conventional solvent based spray painting have been approached by both improving painting techniques and developing processes which either reduce or eliminate solvent thinners in paint, change to more acceptable solvents, or replace the solvent with water.

Some of the more promising developments are:

Powder Coating technology, also called "dry powder painting," is based upon the deposition of special heat-fusible plastic powders onto metallic substrates. Powder coatings are applied by powder spray guns, fluidized bed

methods, electrostatic deposition, or plasma spray techniques.

The fluidized bed method works by immersion of a preheated (up to 350° F) substrate in a dense powder cloud. The powder cloud tends to "wet" or melt onto the surfaces of the immersed object. For larger parts, the curing process is usually completed in a curing oven.

Electrostatic deposition in dry powder applications works by attraction between charged, dry paint particles and an electrically grounded (negative), or positively charged substrate. The process can be accomplished either in a fluidized bed, as previously described, or by spray procedures. The fluidized bed method is limited to relatively flat articles, though advances to get around this limitation are being made. By spraying the charged coating onto an oppositely charged substrate, coatings as thin as one mil (0.001 inch) can be applied.

A novel method to apply dry powder is by plasma spraying, where an extremely hot (5,000 to 15,000° F) gas stream is used to melt and carry the paint particles onto the substrate. This can be advantageous in applications to aluminum alloy substrates (found in many aircraft). The aluminum loses tensile strength above 275° F, and oven-curing is done at about 350° F. However, the plasma coating can be applied such that the substrate does not exceed 185° F with no further curing required. The plasma process is still being developed.

The advantage to all powder coating techniques is that solvent usage is eliminated, paint overspray is often minimized and can be recycled as well. There is virtually no hazardous waste disposal problem.

Wet Electrostatic Painting is a process similar in theory to deposition of dry powder coatings by electrostatic attraction but containing some solvent as thinner (the solvent content is lower, however, than conventional spray painting). Overspray is minimized if not eliminated, resulting in hazardous waste reduction. Electrostatic painting is quite popular for painting aircraft parts and other small, complex, non-aluminum metallic articles. There is, however, concern over the potential safety hazard of imparting voltage on an aircraft which may still contain fuel vapors.

Electrocoating is a sophisticated immersion technique which is not commonly used for military applications. It has found use in industry, however, especially in automotive body coating. Similar in concept to metal plating, an electrically conductive part is dipped in a bath containing

ionized material (paint). The ionized material forms a uniform deposit on the metal or part being immersed. A significant reduction in the requirements for paint solvents have been realized by using this technique (3).

Solvent Reduction is a technique in which a significant reduction in solvent usage (and hence solvent waste) can be achieved by increasing the relative amount of solids in paint. In addition, better coverage is achieved and thus less paint is required than with conventional solids content. However, at the higher viscosities resulting from concentrating solids, more careful temperature control and higher transfer efficiencies are required. In many applications, paint heaters or electrostatic atomization is required.

Waterborne Coatings have also been tried both in industry and the military. By replacing the potentially hazardous solvents in paint with water, significant reductions in hazardous waste generation have resulted. It is the general industrial opinion that water based coatings do not provide the same overall protection that solvent based coating does. Consequently, water based coatings are thought to be more suitable in areas where decoration is more critical than protection. They are especially popular for nonmetal substrates.

Positive results with water based primers, however, have been achieved at Naval Air Rework Facilities (NARF's) when applied to completely stripped surfaces. Water based primers are slower to dry than solvent based. Nevertheless, some naval facilities have experience which shows water based primers to be superior overall due to ease of application, decrease in overspray, lower rejection rate, and ease of cleanup. Water based primers do not perform well when the surface is oily, which is a fairly common condition with a complex piece of machinery that uses oil, such as an aircraft.

Improved Painting Techniques can improve product quality, increase production rates, and reduce the generation of hazardous wastes. For example, by using a conveyor system to paint parts, human contact is minimized and slops and spills of solvents are reduced. Improvements in spray booth and ventilating system design have reduced hazardous waste generation as well. Airless sprayers have also been used to reduce overspray, fogging and subsequent emission of VOC's (volatile organic compounds) for painting applications on very large surfaces (i.e., large aircraft).

Robotics usage has tremendous potential for hazardous waste reduction both in painting and paint stripping applications. Not only could overspray and spills be reduced, but the

higher temperatures required for application of "low" and "no" solvent formulations could be achieved without human discomfort. Unfortunately, the use of robotics is better suited for private sector industries in which there is a mass production of vehicles and parts. Most military manufacturing and rework facilities paint and paint strip an extremely diverse number of parts and materials. These facilities are often not amenable to computerized control robotics since there is a wide range of variables (part sizes, shapes, materials, quantities, etc.) that can change during the course of a day.

4.4 Case Studies

4.4.1 Electrostatic Dry Powder Painting, Hughes Missile Division Case No. 2

At Air Force Plant No. 44, operated by Hughes Aircraft Company-Missile Systems Group in Tucson, Arizona, the wet spray technique is currently used to paint most parts used in the fabrication of missiles. Solvents are therefore used as carriers in the paint and in cleanup operations.

In the paint spray booths, overspray is collected in a conventional air ventilation system equipped with a recirculating water curtain. The solvents and paint collected in both systems are disposed of as hazardous waste.

As an alternative to conventional spray painting, wet electrostatic painting was used to paint spools for the TOW missile. Use was discontinued, however, due to problems with the electrically non-conductive materials used in the spools. Conventional spray painting in spray booths is now being used for this application.

Powder coating is presently being used for the interior of the fuselage section for the Phoenix missile. This technique has proven to be superior to the previous wet spray application because of better coverage on hard-to-reach surfaces. Fewer coatings are required, less equipment maintenance is needed, and hazardous waste generation is reduced. Consequently, significant cost reductions have been achieved. Estimates were made that powder coatings could be applied for approximately one-third the cost of conventional wet spray painting, due in large part to the reduced number of coatings required. The technique, however, requires highly skilled operators - hence, extensive training is necessary.

4.4.2 Spray Painting, Lockheed-Georgia Company Case No. 3

This site is a government-owned, contractor-operated facility in Marietta, Georgia, at which newly manufactured aircraft and aircraft parts are painted. Lockheed-Georgia Company (LGC) operates the plant and is responsible for manufacturing C-130 and C-5 aircraft and modifying C-141 and C-5 aircraft. Thirty-six paint spray booths are used in the painting facilities, four of which are dedicated for painting entire, finished aircraft. Twenty-one of the booths are water wall, the remainder are dry wall. Conventional spray guns are used exclusively at the facility, applying primarily solvent-based, zinc chromate primer. The primer consists of 20-22 percent solids and is a mixture of one part paint to two parts toluene. Lacquers are cut one part paint to one part toluene paint thinner. Lockheed has investigated reducing solvent use, and consequently solvent wastewaters and paint sludge, by increasing the percent solids in the primer. It was difficult to control paint thickness since the dry film would build up quickly on complex shaped parts; therefore, this process modification was abandoned.

Waste products from this painting process consist of about 50 drums/year of paint sludge, and 170 drums/year of spent solvent, while over 125 tons/year of VOC's (volatile organic compounds) were emitted in 1983. Waste solvents consist primarily of 1,1,1-trichloroethylene which is used in vapor degreasers, along with smaller quantities of toluene, which is used to thin paint, and methyl ethyl ketone and xylene, which are used in cleanup operations. Wastewater from water wall spray booths is discharged to the industrial waste treatment plant. The waste solvent is sold for \$0.15 a gallon to an outside contractor for recovery. Paint solids are removed from the water wells once a week and placed in 55 gallon drums. The solids are sent to Chemical Waste Management, Inc.'s hazardous waste landfill located in Emelle, Alabama at a cost of approximately \$60 per drum.

In 1980, a modern conveyor system was installed in the line used for painting small aircraft parts. Lockheed personnel spray paint aircraft parts as they move along the conveyor system. Parts can be plated, painted twice, and oven cured--if necessary, without being touched by human hands. After parts are spray painted, the paint racks are cleaned in a salt solution which removes any paint solids and impurities. This cleaning process produces small quantities of a hazardous paint sludge. Using the conveyor system for small aircraft parts has the following advantages:

1. Product quality is improved since impurities due to human contact are minimized.

2. A wide variety of part sizes and shapes can be handled by the conveyor system.
3. The speed at which the parts are painted is increased, since multiple handling is not required.

In conjunction with the new conveyor system, Lockheed has been retraining operators and inspectors on the proper paint thickness that should be sprayed on parts. There is a tendency for operators to overspray parts with the primer coat. Overspraying an aircraft part results in excess weight for the aircraft. For example, if a C-5 aircraft is coated with 6 mil of primer instead of the specified 3 mil, the aircraft's weight will increase by several hundred pounds. The primary motivation of the training program is to reduce aircraft weight and paint material cost. If the training program is successful, the quantities of waste solvents and paint sludges should also be substantially reduced.

Lockheed has investigated several alternatives to solvent based, human operated spray paint systems. In each case, the proposed modification was not permanently implemented. These changes were:

1. Robotics - To improve product quality and efficiency, and reduce paint overspray, robotics were attempted. The robot had the capability to paint an 8 foot by 6 foot rectangular area and could be used for both normal spray painting and electrostatic painting. Usage was discontinued, however, because of difficulty in spraying the irregularly shaped aircraft parts.
2. Water based primer - To reduce hazardous waste generation, Lockheed tested water based primers to determine if they could replace solvent based primers. Lockheed was hesitant to change water based primers because they felt that the useful life of these primers was shorter than the useful life of solvent based primers. While water based primer does meet the military specifications requirement for a useful life of 500 hours, solvent based primers can last up to 2,500 hours. Therefore, Lockheed will not replace solvent based primers with water based primers unless the performance of the solvent based primer can be met or exceeded, regardless of the quantities of hazardous waste produced. Lockheed personnel believe that solvent based paints are lighter for the same thickness as water based paints, less

expensive, easier to apply, easier to remove for inspection, and more durable than water based primers. Solvent based primers also dry much more rapidly than water based primers. If Lockheed were to replace solvent based primers with water based primer, ovens would have to be installed to hasten the drying of painted aircraft parts.

A small amount of water based painting is done at Lockheed for in-house protection of spare parts. A primer coat is sprayed on parts to protect them from scratching and corrosion while in storage. Drying ovens have been installed so that parts can be immediately shelved after being painted.

3. Powder Painting - In order for powder coatings to be activated, the coating and substrate had to be heated to 350°F. Since the majority of aircraft parts at the site contained aluminum which cannot be heated above 250°F, the study was discontinued.

4.4.3 Painting Modifications at Naval Air Rework Facilities (NARF's) Cases Nos. 27, 28, 34

In contrast to the situation at Lockheed described above, water based primers have been successfully implemented at several NARF's. Pensacola NARF has a strong program underway for conversion from solvent based to water based primers. The NARF at Jacksonville, Florida has been using water based primers successfully for the past year, while the NARF at North Island has just recently begun use of water based primers.

In the past, the NARF at Pensacola has had considerable problems with solvent based chromate primers. Twenty percent of the painted parts had to be rejected because they did not meet product specifications. Pensacola personnel hypothesize that the high rejection rate was due to inferior paint which did not meet military specifications. The Government Services Administration (GSA) reportedly does not adequately test to determine whether a manufacturer's paints meet military specifications. Since switching to water based painted parts, a 98 percent acceptability rate has been achieved.

Drying ovens at Pensacola and Jacksonville are unnecessary due to the favorable Florida climate. During summer, a top coat can be sprayed on a part one-half hour after the application of the primer. During winter, a part must dry for one to two hours before it can be repainted.

A serious drawback to the water based epoxy primers used at Pensacola has been the "unforgiving" nature of the paint. This means that if any oil is present on the surface to be painted, the water based coating will not adhere well, and will tend to blemish the surface. For example, many of the aircraft painted at Pensacola are given camouflage coloring. The complex aircraft machinery, with various gearboxes and other oil using parts, naturally tend to ooze some oil. The camouflaged finish is dull and porous, and consequently absorbs oil. It is not surprising that they have had difficulty with water based primers on these aircraft.

Most of the aircraft that are reconditioned at Jacksonville, however, have tight, glossy finishes. The oil from these aircraft is easily removed and water based coatings work very well.

In essence, the general feeling of NARF experts is that water based primers will work very well in selected applications, especially for parts which have been completely stripped.

Other painting techniques have been tried at Pensacola, but were discontinued. Electrostatic painting, for example, was tried several years ago. However, military specifications called for certain additional solvents to be added to the paint to impart the proper electrostatic charge. Unfortunately, these additional solvents apparently were not compatible with the paint. The success they did have did not warrant the trouble to convert to electrostatic operation. Electrostatic powder painting could only be applied on a selective basis. Pensacola personnel believe that electrostatic painting is more applicable at a manufacturing facility than a rework facility.

Pensacola has had moderate success in applying epoxy paints with various spray guns (airless, dual media, etc.), but equipment problems inevitably caused the projects to be discontinued. While using airless guns, for example, they observed better paint deposition, but had problems with the high degree of operator skill necessary to properly operate the system. Conventional air spray guns have been found to be most reliable due to ease of maintenance and simplicity.

At the Alameda, California NARF, high pressure (up to 3000 psi) airless sprayers have been used for the past ten years for painting larger aircraft. The airless sprayers cut fogging and overspray, but use nozzles which are difficult to control. They are less efficient for smaller applications where spray flows must be constantly varied to spray into corners, etc. About 95 percent of the paint used for the airless sprayers at Alameda are epoxy polyamide primers. They plan to switch to water based primers in the near

future based on their success at other NARF's and the reduction in hazardous waste produced.

4.5 References

- (1) Brewer, G.E.F., "Compliance Solvents for Formulation and Thinning of Spray Paints," Metal Finishing, January 1984, p. 23-28.
- (2) Moore, Gardner and Associates, Naval Shipyards Industrial Process and Waste Management Investigation, US Government contract N00025-80-C-0015, July 1983.
- (3) Brewer, G.E.F., "Electrodeposition Coating With Aqueous Latexes," Polymer News, Vol. 3 No. 4, April 1976, p. 204-208.
- (4) Joseph, R.M., "New Paint and Organic Coating Technologies are Exploding," Metal Finishing, May 1984, p. 25-27.
- (5) Ziegeweid, J.E., "Which Paint for Us (and why) - Part II," Metal Finishing, November 1984, p. 71-73.
- (6) Cole, G.E., "VOC Emission Reductions Achieved by Major Powder Coating Operations," Paper presented at the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, California, June 24-29, 1984.
- (7) Minuti, D.V. and Devine, M.J., Innovative Application of Materials for Aircraft Wear Prevention, Naval Air Development Center, Warminster, Pennsylvania.

WDR93/06

Metal Plating

5 METAL PLATING

5.1 Process Description

Plating is defined as the deposition of a thin layer of metal on the surface of a basis metal for the purposes of changing the properties of the basis metal. These modifications may be to improve the appearance (decorative plating), to increase resistance to corrosion, or to improve engineering properties (hardness, wearability, solderability, or frictional characteristics) of the basis metal. Plating is a subset of metal finishing, which includes painting and operations that modify the properties of the basis metal (i.e. anodizing of aluminum).

The principal metals plated at military facilities are chromium, cadmium, nickel and zinc.

Chromium is used principally in the remanufacturing of worn parts that are infeasible to replace with new parts because of their unique design. Remanufacturing consists of stripping a portion of the old plate, overplating with a thick layer of chromium (hard chrome plating) and machining back to original specifications. The remanufactured parts are often of better quality than the original parts due to the thick chromium plate. Parts are typically plated for longer than 24 hours, to achieve the required thickness of chromium.

Hexavalent chromium is commonly used in chromium plating bath formulations and is a major concern in the design of waste treatment processes for chrome plating facilities. Chromium must be reduced to its trivalent form before it can be removed by precipitation with the other plating metals in an industrial wastewater treatment plant. This complicates and adds significantly to the treatment process.

Nickel, cadmium, and zinc are plated to provide a corrosion protection finish to parts. These coatings are significantly thinner than hard chrome plates, and are applied in minutes, rather than the hours or days required for hard chrome plating. Nickel is applied to new parts for corrosion and wear resistance as well as for rebuilding worn parts. A thin nickel plate is sometimes applied prior to hard chrome plating.

Sacrificial cadmium and zinc coatings are normally applied to protect the basis metal, typically iron or steel. A thin surface coating is normally applied to provide corrosion protection, improve wear or erosion resistance, reduce friction, or for decorative purposes. Since cadmium is significantly more expensive and toxic than zinc, it is only used

s a protective electroplate in those circumstances in which its special properties are required.

cadmium is selected as a protective coating for the following reasons: (1) cadmium is more easily soldered than zinc; (2) its corrosion products do not swell and are not bulky unlike the "white rust" formed by zinc, and hence do not interfere with functional moving parts; (3) cadmium plating is easier to control than is zinc plating; and (4) cadmium is somewhat superior to zinc in corrosion protection in marine (salt) environments. For these reasons, cadmium is often chosen over zinc in military applications.

Parts that are to be cadmium plated typically are cleaned of grease, oil, dust and rust by undergoing solvent vapor degreasing, alkaline cleaning, and acid pickling. Once a part is cleaned, it is cadmium plated, and then heated to remove hydrogen (to prevent hydrogen embrittlement).

In the past, cadmium has almost universally been plated from an alkaline cyanide bath. Unfortunately, cyanide baths are dangerous to operate and the resulting cyanide-containing wastes are complicated and costly to treat.

5.2 Magnitude of Problem

The major discharges of hazardous waste from typical metal plating facilities are: rinsewater contaminated by drag-out from various processing baths; cleanup of spills; aerosol spray from such operations as chromium plating that is exhausted to the atmosphere or removed by wet scrubbers; and discarded process solutions.

A review of Army plating operations was performed by Chesler (10). He found that 23 DARCOM installations perform metal plating or finishing operations, with wastewater productions varying from less than 100 gallons per day to over 150,000 gallons per day. Metals plated at these facilities include chromium, cadmium, nickel, zinc, tin, lead, brass, and gold. He found that the principal sources of hazardous waste generation at Army plating facilities were drag-out to rinsewater, spills of plating solutions, disposal of acid and alkaline cleaners, and occasional plating bath dumps.

Metal finishing processes were being used at more than 70 Navy facilities, according to a report by Centec Corporation (5). The largest naval electroplating operations were found at Naval Air Rework Facilities (NARF's), Naval Shipyards (NSY's), Naval Air Stations (NAS's), the Naval Ordnance Station (Louisville, KY), and the Naval Avionics Center (Indianapolis, IN). Metals plated included copper, chromium, cadmium, nickel, tin, lead, zinc, brass, gold, silver, iron and rhodium. Wastewater production at the

employing approximately 4,500 people. The principal mission of the facility is to recondition used tanks and other armored vehicles. Approximately 700 tanks are reconditioned at the facility each year.

Reconditioning consists of complete disassembly of tanks and dismantling of their components. Paint, rust and dirt are removed from components prior to remanufacturing. Paint is removed by sand blasting or stripped using organic solvents or alkaline strippers. Greases and oils are removed using solvent vapor degreasers, followed by alkaline cleaners. Rust and oxide films are removed by sand blasting and acid pickling.

Worn parts that would be infeasible to replace new are reconditioned by overplating with chromium (hard chrome plating) followed by machining back to original specifications.

The existing plating facility is approximately 3 years old and is a very clean, well organized and well managed facility. Many current waste reduction features were considered in the design of the facility. Baths are carefully maintained and the need for bath dumps is almost totally eliminated. When the old plating shop was closed, baths were transferred to the new facility. It was claimed by the plating shop foreman that, in 27 years of operation, only one bath had been dumped, and that because of contamination due to installation of an improper liner in a tank. Elimination of bath dumping has been accomplished by careful recleaning and waxing of parts.

Central filtration systems for each of the different bath chemistries are located in the basement of the plating shop. These systems consist of storage tanks, pumps and Serfilco cartridge filters. Most baths are filtered 2 to 3 times per week. The filtration system for chromium baths is used infrequently, due to careful pre-cleaning and waxing of parts and the inherently low loading rate on the hard chrome tanks.

Insewer tanks are of single flow-through type with flow rates controlled by conductivity. At other DOD facilities, considerable problems have been encountered in maintaining conductivity control systems, with the result being that these controllers are frequently bypassed. The conductivity controllers at this facility appeared to be in good working condition, with minimal problems encountered in their use.

Countercurrent rinsing was considered for the facility, but was not used because of budget restrictions, and the plating supervisor did not feel that the reduced treatment costs offset the additional construction costs. He had seen the

felt to be significant, and temporarily exceeded the lead limit.

The plant has been plagued by operational, maintenance and design problems that have hampered the plant's ability to provide reliable and efficient treatment. The plant operation and maintenance manual was inadequate, inaccurate, poorly organized, and virtually unreadable. Operator training by the equipment vendor was rated as inadequate. The system was crowded into an extremely limited space, such that some anticipated repair procedures would require moving the entire treatment unit to provide access.

The chromium reduction reaction tank had sprung a leak, and had been bypassed for about two weeks at the time of our visit. The operators noted that provisions had been provided in the O&M manual to utilize the ferrous addition in the main treatment system for chromium reduction as well as coagulation. The plant was reported to be meeting its chromium effluent limitations by this alternate treatment scheme. A new plastic tank was on order to replace the failed lined steel tank.

The treatment system was designed to segregate and treat cyanide wastes by two-stage alkaline chlorination. This system is in operation. Since installation of the system, the plating shop has converted to non-cyanide plating baths. Continued operation of the cyanide treatment system is of questionable benefit.

It would be of benefit to determine if the separate treatment of chromium and "cyanide" wastes is still necessary. Elimination of these processes would greatly reduce the complexity of the treatment system and eliminate the need for some chemicals. The effectiveness of alkaline chromium reduction using ferrous iron and sulfide has been demonstrated in the literature and in actual practice at the facility. Additional studies would be needed to verify this before permanently implementing this change.

The efficiency of the clarifier/filter system is compromised by a frequent on/off cycling of the influent pumps. It would be beneficial to modify the feed system to better pace the inflow rate to the sumps. The planned addition of an equalization tank would help reduce this variation in flow as well as increasing the capacity of the treatment plant if 24-hour operation is used.

5.4.7 Plating at Anniston Army Depot Case No. 18

Anniston Army Depot, constructed in 1941, is a government-owned, government-operated (GOGO) industrial facility,

demonstration of the soluble sulfide precipitation process for the treatment of a metal finishing wastewater. Soluble sulfide precipitation was selected because the lower solubility of metal sulfides was expected to result in better metal removal efficiency than conventional hydroxide precipitation. Metal sulfide sludges were expected to be more easily thickened and dewatered and less easily leached than metal hydroxide sludges.

The three segregated wastes were treated separately. Cyanide containing wastes were treated in a two-stage alkaline chlorination process for complete cyanide oxidation. Chromium-containing wastes were acidified to pH 2.5 and treated with sodium metabisulfite to reduce hexavalent chromium to the less soluble trivalent form. Following separate treatment, these wastes were combined with the acid/alkali and circuit board wastes for treatment by soluble sulfide precipitation.

Soluble sulfide precipitation system consists of pH adjustment with caustic soda, addition of ferrous sulfate and anionic polymer as coagulants, addition of sodium sulfide to precipitate metals, flocculation, parallel plate clarification, gravity sand filtration, and peroxide destruction of residual sulfide. Sludge processing consists of gravity thickening and dewatering in a plate and frame filter press. Filter cake is drummed for disposal off-site in a hazardous waste landfill by American Recovery of Baltimore, Maryland. Approximately one drum of dewatered sludge is produced per week. EP Toxicity testing resulted in a finding that the sludge was a hazardous waste, principally due to cadmium leachability. Any reduction in leachability due to sulfide precipitation was therefore of no practical benefit, with respect to its hazardous waste classification.

The treatment plant was designed with a capacity to treat 18,000 gallons per day of combined waste from the plating and circuit board shops. Along with construction of the treatment facility, flow limiting and monitoring devices were installed on rinsewater tanks in the plating shop. Following installation, flow from the plating shop was reduced to about 10,000 gpd. These flow reducing efforts have not been maintained. From 35,000 to 50,000 gpd of wastewater is now being produced, far in excess of capacity of the pretreatment system. As a result, the acid and alkali and printed circuit board wastes have been diverted directly to the sanitary sewer and are not pretreated. A controversy exists over keeping rinsewater flows to the minimum needed to maintain good product quality. Metal concentrations in the waste are considerably lower than are typical for efficiently operated countercurrent rinsing.

The treatment plant has been meeting its design performance standards, with the exception of aluminum, which was not

communications equipment. Wastewaters containing metals are generated by the metal finishing shop and the printed circuit board fabrication shop. These wastes are treated in an industrial waste pretreatment plant prior to being combined with other wastewaters for treatment in a trickling filter plant and subsequent discharge to a stream.

The metal finishing shop operates as a "job-shop," plating and finishing an assortment of small parts on an as-needed basis, utilizing 32 process and 32 rinse tanks. Processes utilized include copper, nickel, chromium, cadmium, tin, and silver plating, anodizing, etching, phosphating, and immersion coating. Metal finishing is provided principally for corrosion protection and to modify surface electrical properties of the basis metals. No hard chrome plating is performed.

Rinsewaters from the plating shop are segregated into three waste streams as follows:

- o those containing cyanide
- o those containing chromium
- o other acid and alkaline wastes

These waste rinsewaters are pumped separately to the pretreatment facility.

Concentrated waste solutions are pumped into drums and disposed of as hazardous waste, rather than being bled to the treatment plant. Hydrochloric acid and bright dip solutions are dumped approximately once every two weeks. Other solutions are dumped at 6 to 9 month intervals. Approximately 200 drums of concentrated waste are produced each year by the plating shop, mostly waste alkaline and acid cleaners. Plating baths themselves are rarely dumped, but are tested and maintained by chemical addition.

The printed circuit (PC) board operation manufactures the various PC boards needed for rebuilding and repairing electronics and communications equipment at the depot. Waste produced by the PC board facility is principally rinsewater from plating and etching processes. Rinsewaters contain lead and copper, and are combined with acid and alkaline plating wastes for treatment in the industrial pretreatment plant. Concentrated solutions are drummed for disposal as hazardous waste. Approximately 10 drums of waste are produced each month, and contain mostly waste etching solutions.

The 18,000 gallons per day (gpd) industrial pretreatment facility was designed and constructed as a full-scale

5.4.5 Steam Condensate Recovery at Pensacola NARF Case No. 11

Plating baths at Pensacola NARF are operated at elevated temperatures to increase the speed of plating and to improve the quality of the plate produced. The plating baths are heated by steam coils located in the baths. Presently, after its heat value is extracted, steam condensate is disposed of.

Evaporation averages about 8 gallons per hour for the plating tanks used at Pensacola NARF. These evaporative losses are made up by addition of deionized water, at a cost of \$37.90 per thousand gallons.

A condensate collection, storage and distribution system is being installed to recover steam condensate in the plating shop and use it to make-up evaporative losses from the plating baths; thus reducing the need for deionized water. The recovery system will consist of a 4,000 gallon storage tank, pumps, conductivity controller, and a piping system to each of the plating tanks.

It has been estimated that a minimum (during summer months) of 4,000 gallons per day of condensate would be available for recovery. This is compared to an estimated evaporation rate of 6,000 gallons per day from the 30 plating tanks requiring deionized water makeup. Replacing this deionized water with condensate would result in a savings of approximately \$47,000 per year. With a construction cost of \$38,000 the condensate recovery system was estimated to have a payback period of less than 10 months. During winter months, excess condensate would be available for selected rinse or other uses.

One concern is that the quality of the steam condensate is not equivalent to deionized water. Care must be used in selecting applications for its use. A conductivity meter is being installed in the distribution system so its quality can be monitored.

The system has been designed, bids solicited, and is awaiting approval for construction. Since the system has not been constructed, no operating experience was available.

5.4.6 Metal Sulfide Precipitation at Tobyhanna Army Ammunition Plant Case No. 16

Tobyhanna Army Depot, a government-owned, government-operated facility constructed in 1953, employs approximately 4,300 people to rebuild and repair electronics and

Clean rinsewater is available with a hand-held sprayer. After repeated use, a portion of the rinsewater is pumped through a cloth filter into the plating tank and added to the plating bath to replace water lost through evaporation.

Without drag-out to aid in removal of contaminants from the bath, a cleanup process was required to reduce the need for plating bath dumps. A "Cat-Napper-10" treatment system, manufactured by Innova Technology, Inc. of Clearwater, Florida, was installed to continuously remove cations from the chromium plating bath. The "Cat-Napper" system utilizes a cathode contained within a membrane module to selectively precipitate trivalent chromium and other cations from the plating solution. Hexavalent chromate ions remain on the anode side of the membrane, and are returned to the plating bath.

The process modifications resulted in the average plating rate increasing from 0.002 to 0.004 inches per hour. There was also a significant increase in production because the rack design enables a significantly greater number of parts to be plated in the same tank. Combining the effects of increased plating speed and plating rack design resulted in a six fold increase in production.

The operators felt that the spray rinse system was an improvement over the previous countercurrent rinse system. Water use was reduced from 350,000 gallons per month per bath for countercurrent rinsing to about 1,200 gallons per month of fresh water for spray rinsing. Since this amount was less than the evaporation rate, all of the spray rinse was returned to the plating bath, resulting in a "zero discharge" condition.

The spray rinse system was projected to recover 108.7 pounds of chromic acid at an approximate savings of \$128 per year. A total savings of approximately \$25,000 per year per bath was projected, principally due to reduced industrial wastewater treatment costs.

The Cat-Napper system did not effectively remove contamination from the chromium plating bath, during an initial trial run. The system was plagued by failure of membrane modules, caused by a change of material by a supplier. Replacement with new modules has resolved this problem. Further testing is required of this technology before further application could be recommended. Additional studies are also recommended to determine the limits of contamination that would be acceptable for a hard chrome plating bath before plating quality is diminished.

in the vapor-recompression distillation unit. The system was a net consumer of deionized water, used for cooling of the vacuum pump.

The new vacuum pump is not expected to have a long operating life. the corrosive nature of the process solutions was apparently not adequately considered in design of the system. This is a high priced item (\$10,000 in carbon steel as the two previous pumps were, or \$80,000 in stainless steel).

The exterior of the LICON unit showed deterioration due to exposure to chromic acid solutions. Overall, the LICON unit did not appear to have a long useful life.

The status of the LICON unit at the time of this writing (January 1985) was that the ion exchange module was being used for bath cleanup and the vapor recompression module was being scrapped.

5.4.4 Innovative Chromium Plating at Pensacola NARF Case No. 10

The innovative chromium plating system developed by Naval Civil Engineering Laboratory at Pensacola NARF is described by Carpenter (2). The hard chrome plating process had been developed in the Cleveland area about 50 years ago. Modifications, developed by these platers and termed "Reversible Rack 2 Bus Bar System", were incorporated at Pensacola NARF.

Modifications to standard Navy chromium plating practice were:

- (1) Operation at higher temperature
- (2) Use of conforming anodes and reversible racks to clamp parts and anodes to
- (3) Control by voltage rather than by amperage
- (4) Use of a recirculating spray rinse system
- (5) Use of a "Cat-Napper" to remove cations from the plating solution

The first three modifications resulted in increased plating bath evaporation. A recirculating spray rinse system reduced rinsewater requirements sufficiently so it could be used for plating bath makeup. The spray rinse system was installed in an existing rinse tank. A pump recirculates rinsewater through eight high velocity spray nozzels located around the perimeter of the rinse tank. The pump is activated by a foot peddle as parts are lowered into the tank.

A reliability, availability and maintainability (RAM) study was performed by Carpenter (1). The reliability and operational availability of the LICON unit was rated as very poor, principally due to problems with the vapor recompression unit. In summary the report stated:

The LICON vapor recompression unit appears sound in theory, but needs more work before it will be a reliable, viable alternative to consider for use in metal recovery...Economically, the LICON unit is a liability at NARF Pensacola.

The LICON unit was transferred to Charleston Naval Ship Yard (NSY), South Carolina, for further evaluation on the chromium plating line at that facility. This application of the unit is evaluated as Case No. 12 of this study.

5.4.3 LICON Chromium Recovery at Charleston NSY Case No. 12

A description of the LICON unit is presented in Section 5.4.2 of this report. Following difficulties at Pensacola NARF, the unit was shipped to Charleston NSY for further evaluation. Following replacement of the high vacuum pump, the unit was installed to recover chromium from rinsewater on the hard chromium line.

The long plating times and over-capacity of the plating shop resulted in an extremely low drag-out rate (0.08 gallons of plating bath per hour). Countercurrent rinse and careful control of the inlet valve resulted in a rinsewater flow rate that was less than the evaporation rate from the plating bath, eliminating the need for rinsewater concentration. An insignificant amount of chromium has been recovered from the rinsewater by the LICON unit.

The LICON unit was successfully used to clean up waste plating solutions. These plating solutions were first diluted to prevent destruction of the ion exchange resins in the cleanup module, and then concentrated back to bath strength in the evaporation unit. These reconstituted baths successfully passed plating tests.

The LICON unit is complicated, has required close supervision, and experienced constant and expensive maintenance. Approximately three man-hours per day were required for operation and recurring repairs, due to failure of seals, pumps and other problems. The system was not capable of continuous operation for more than a few days.

Distilled water produced by the vapor recompression unit was of unacceptable quality due to iron contamination, probably from corrosion of the high-vacuum pump, an essential element

vapor recompression unit was to be of distilled water quality, and thus a beneficial byproduct.

At the time that the LICON unit was installed, NARF Pensacola operated four separate chromium plating lines, each equipped with three-tank countercurrent rinse systems.

An evaluation of the LICON unit's performance at NARF Pensacola was prepared by Carpenter (1). An annual savings of 35,000 pounds of chromium had been projected for the unit at this installation, based on the false assumption that the drag-out rates and rinsewater chromium concentrations would be the same as those of commercial platers. However, the maximum chromium drag-out measured at Pensacola, and thus available for recovery, was approximately 90 pounds a year. The unit proved incapable of concentrating the recovered chromium up to bath strength.

Pumice, used in the plating operation, was carried over into the rinsewater. No provision was provided for pumice removal in the LICON unit, and so the pumice was concentrated along with the chromium, making the concentrated chromium solution unacceptable for reuse. Carryover of wax was also a problem, but was eliminated by the installation of a filter prior to the ion exchange unit.

The low amount of chromium recovery, due to the low drag-out rate from the hard chrome plating lines, made the operation uneconomical, with a cost of approximately \$1,500 per pound of chromium recovered (1), compared with a replacement cost of less than \$2 per pound for new chromium.

The use of brighteners and additives to the plating baths resulted in foaming in the LICON evaporator unit resulting in carryover. The distilled water produced by the unit was of poor quality due to this carryover and contamination by compressor oil.

Another problem with the vapor recompression unit was that it utilized 20 gpm of cooling water to condense 20 gph of distilled water. This cooling water was discharged to the industrial wastewater treatment plant with a treatment cost of \$5.37/1,000 gallons. During the year and a half of operation this resulted in a cost of \$194.51 per day to produce 552 gallons of poor quality distilled water and to recover approximately a half pound of chromium that was unsuitable for reuse.

The high vacuum pump deteriorated rapidly, and could not pull its rated vacuum, severely limiting the efficiency of the process.

containing wastes were pumped into 55-gallon drums and trucked off-site for disposal. The new plating bath, called "Cadize Plating Solution", is manufactured by Learonel, Inc. This proprietary bath is composed of cadmium oxide, sulfuric acid, two brighteners, one starter, and one stabilizer.

According to Mark Batich, Manufacturing Engineer at Lockheed, produce quality before and after the changeover to non-cyanide cadmium plating baths is equivalent.

Operating costs have decreased slightly since changing to the non-cyanide plating baths. The new plating solution, costing approximately \$3 a gallon, is more expensive than the old cyanide-containing formulation. The reduced waste treatment costs, however, result in a net cost savings from this modification.

Approximately half of the contents of the cadmium plating baths are dumped to the industrial wastewater treatment plant each year to partially remove impurities from the tanks. These dumps are usually the result of a buildup of excessive concentrations of cadmium. Cadmium anodes are left immersed in the baths for long periods when the plating line is not in operation. The cadmium anodes slowly dissolve in the acidic plating solution, resulting in an excessive buildup of cadmium.

5.4.2 LICON Chromium Recovery at Pensacola NARF Case No. 9

The Naval Air Rework Facility (NARF) at Pensacola is a government-owned, government-operated (GOGO) facility employing approximately 4,000 people. The mission of the facility is to recondition helicopters and airplanes. Reconditioning consists of disassembly of the aircraft and components, paint stripping, removal of dirt, grease and corrosion products, remanufacturing or replacement of parts, reassembly, and application of protective coatings (plating and painting). Worn parts that would be infeasible to replace new are remanufactured by overplating with chromium (hard chrome plating) followed by machining back to original specifications.

The LICON unit, manufactured by LICON, Inc., was designed to reduce or eliminate chromium waste discharge from the plating shop, by recovery and cleanup of chromium from the rinsewater. The LICON system is composed of two basic modules, an ion exchange module used to remove cations (principally iron and trivalent chromium) from the dilute rinsewater, and an evaporation unit for concentration of the clean rinsewater to plating bath strength. The evaporator unit utilizes vapor recompression and waste heat recovery to reduce energy consumption. The condensate produced by the

from these areas. Parts should not remain in the baths longer than necessary when not being plated.

Alternatives to dumping of contaminated baths are available. Metal contaminants can be removed by electrolysis, chemical precipitation, and other means. Particulates can be removed by filtration. Organic contaminants can be removed by activated carbon adsorption.

Traditionally, cadmium has almost universally been plated from alkaline cyanide baths, due to the improved plate resulting from the stable cadmium cyanide complexes. Unfortunately, cadmium cyanide baths are costly and dangerous to operate and the wastes generated are difficult and expensive to treat. Alternative baths containing fluoborate, sulfate and chloride anions have been developed to replace cyanide baths. Vacuum deposition of cadmium has been developed to replace electroplating. Recently, ion vapor deposition (IVD) of aluminum has been developed to replace cadmium as a protective coating.

5.4 Case Studies

5.4.1 Cadmium Plating at Lockheed-Georgia Company. Case No. 6

Air Force Plant #6, located in Marietta, Georgia, is a government-owned, contractor-operated (GOCO) facility operated by Lockheed-Georgia Corporation. Employing 15,000, the facility has a working floor space of 7 million square feet and occupies 720 acres. The plant was constructed in the 1940's and has been operated by Lockheed since the Korean War. Lockheed has manufactured all of the Air Force's major cargo planes (C-5's, C-130's, C-140's, and C-141's) at the plant.

Approximately 90 to 95 percent of the metal in these cargo planes is aluminum. The remaining 5 to 10 percent is steel, iron, titanium and molybdenum. Parts made from some of these latter materials are plated with cadmium for corrosion protection.

The Lockheed facility utilizes trichloroethylene vapor degreasing, sodium hydroxide alkaline cleaning, and hydrochloric acid pickling to remove grease, oil, dust and rust from parts prior to their being plated. After cleaning, the parts are cadmium plated, baked to remove hydrogen (to prevent hydrogen embrittlement), immersed in a chromium dip tank, and then painted.

In August of 1983, the plating shop switched from an alkaline cyanide cadmium plating bath to an acidic non-cyanide containing cadmium bath. Previously, cyanide

units have not performed well in most installations, resulting from the probes' lack of ruggedness and need for frequent calibration and cleaning. Many platers have been dissatisfied with their operation and have overridden their controls.

Rinsewater recycling has been suggested, where the overflow from one rinse tank is used for the water supply for a compatible rinse tank (i.e., using acid rinsewater to supply a rinse tank for an alkaline cleaner).

The use of countercurrent multiple rinse tanks can reduce rinse flows by over 90 percent when compared to single overflow rinses. However, multiple rinse tanks require additional space, which is often not available, and add to production time since the plater rinses at more than one tank.

Methods for recovery of metals from rinsewater are currently being developed. These processes are used to increase metal concentrations sufficiently to return them to their respective plating baths. Reverse osmosis and electrodialysis utilize membranes to separate a concentrated salt solution from water. Ion exchange has been utilized to remove metal ions from water, and subsequently elute them from the resin in a more concentrated form.

Evaporative concentration is utilized by itself or in combination with other methods listed above. During evaporation, solvent water is boiled off, leaving a concentrate. Simple boiling can be expensive due to the high heat capacity of water. Sophisticated systems have been developed to improve energy efficiency, such as multiple effect and vapor recompression evaporators. Waste heat is utilized where available.

These recovery methods also concentrate any contaminants and return them to the baths. Methods of bath cleanup would also need to be incorporated. Otherwise the recovered metal may be lost in bath dumping.

Plating bath dumps are performed when contamination reaches a point where product quality deteriorates. Contaminants include the following: secondary metals that result from corroding metal racks and parts to be plated; impurities in the anodes; drag-in of cleaners and pickling solutions; and particles that are carried in on dirty parts or released from the anodes.

Metallic contamination can be minimized by careful preparation of parts prior to plating. Parts should be well cleaned and rinsed. Areas that are not to be plated should be masked or stopped off with tape or wax to limit corrosion

5.3 Proposed Modifications

Several process modifications have been suggested to reduce the generation of hazardous metal plating wastes at their source (3,5,6,7,10,13).

Drag-out reduction can be accomplished by modification of bath viscosity, chemical concentration, surface tension, and temperature. These modifications result in improved drainage of plating solutions back into plating baths, or reduction of the concentration of metal in the drag-out. Lowering the velocity of withdrawal of parts from a bath can drastically reduce the thickness of the drag-out layer, due to surface tension effects. Drag-out can be captured by the use of drain boards or tanks and returned to the bath. Care must be exercised by the plater to rack and remove parts so as to minimize entrapment of bath material on surfaces and in cavities. Air knives have been used to knock plating films off parts and back into process tanks.

Rinsewater modifications have been proposed to reduce flows. Reduction in rinsewater flows may not reduce the amount of toxic metal that is disposed of, but can reduce the volume of liquid waste that must be processed in industrial wastewater treatment plants. However, concentrations of metals would increase, resulting in possible adverse impacts on treatment. If the rinse flow rates are reduced sufficiently, it is possible to utilize rinsewater to make up for evaporative losses in the plating tanks, resulting in metal recovery and reduced waste discharge.

Spray or fog rinse can be used to improve the efficiency of rinsewater use. Drainage can be directly back into the process tank if evaporation is sufficient, or into a drag-out tank. Still rinses can be used prior to a flowing clean water rinse. Water from the drag-out tank or still rinse can be returned to the bath to make up for evaporation losses. Increasing plating bath temperatures to increase evaporation may be justified.

Rinse tank efficiencies can be improved by the addition of air agitation. A control valve on the water supply can be used to reduce flow to the minimum required to effectively rinse parts. Use of timer or conductivity controls have been used to reduce demands on the plating personnel.

Conductivity control is based on the principal that clean water has a lower conductivity than water contaminated with plating solutions. When the rinsewater is renewed, the valve closes automatically. Conductivity controllers have been widely used in military plating shops. They have been installed in 70 percent of Army plating shops (10) and many Naval and Air Force plating shops (5). Unfortunately, these

facilities varied from less than 100 to 360,000 gallons per day. The total wastewater effluent from these metal finishing shops was estimated to be over 3.6 million gallons per day.

Process solutions disposed of were primarily spent alkaline and acidic cleaners used to condition parts prior to plating and to remove metal deposits from rejected or damaged parts. These discarded solutions contained significant concentrations of metals and cyanide due to drag-in from previous process cycles and attack of the base metals by the chemicals in the cleaning solutions. Navy experience has been that the concentration of metals and cyanides in stripping solutions usually exceeds 50,000 milligrams per liter (5).

Another significant contribution of metals and cyanide was the disposal (dumping) of plating baths that failed to perform as required. Dumping of plating baths is rarely practiced in private industry, due to the high costs of chemical replacement and disposal. However, it was reported that many Navy shops dumped plating baths (especially chromium) once or twice a year, usually before plating quality deteriorated, either on a pre-set schedule or based on observation (5).

For hard chrome plating operations, bath dumping is usually the principal source of chromium discharge. Drag-out to rinse tanks is minimized due to the extended plating times of from 24 to 48 hours. Chromium drag-out from a typical naval plating bath was found to be approximately 100 pounds a year (1). It was estimated that the amount of chromium dumped in plating baths at Pensacola NARF was over 20,000 pounds a year, or approximately 170 times the amount lost to drag-out (5). This is in contrast to decorative chrome plating operations, where parts remain in the plating tanks for a minute or less, and drag-out can exceed 35,000 pounds of chromium per year (1). Impurities generated in the plating process are removed in this drag-out, reducing or eliminating the need for bath dumping.

The Air Force was reported to operate 15 electroplating facilities (11). These facilities ranged from the small, 3 to 4 plating bath operation, to the very large operation with over 40,000 square feet of floor space. These shops plated a variety of metals in support of both local maintenance, and periodic major overhaul of engines and aircraft at Air Logistics Centers (14). In addition, plating was performed by private contractors at government-owned, contractor-operated (GOCO) facilities.

spray rinse system at Pensacola NARF (Case #10, Section 5.4.4) but was not sufficiently convinced of its advantages to incorporate this system at Anniston.

Hard chrome plating is performed on a line that consists of 7 plating tanks and 7 rinse tanks, plus assorted tanks for waxing and dewaxing. Parts are plated for 24 to 48 hours. The baths are maintained at 33 ounces of chromium per gallon, with weekly additions to make up for drag-out and plating losses. The reject rate for parts has been only about 2 percent compared to as high as 40 percent at NARF's. Approximately 5 to 6 batches of rinsewater, containing less than 50 mg/l of chromium, are treated each day.

Cadmium is currently being plated from alkaline cyanide baths, using a conventional line and an automated bucket line. Noncyanide containing baths were considered, but rejected by the plating shop supervisor because he felt that the resulting cadmium plate was not as corrosion resistant and that noncyanide cadmium baths had a significantly reduced throwing power, or ability to be plated uniformly on irregularly shaped parts. He also noted that he has never had an accident with the cyanide baths.

Wastes are segregated for treatment. The alkaline cadmium cyanide rinsewaters are treated for cyanide destruction by alkaline chlorination and cadmium precipitation at an optimum pH prior to mixing with other wastes. Chromium rinsewaters are likewise segregated for separate chromium reduction at low pH (2.5) using meta' isulfite and ferrous sulfate followed by alkaline precipitation with other metal containing wastes.

Chromic acid is used at several locations for cleaning purposes. These cleaning solutions are disposed of approximately once every 5 years.

5.4.8 Segregation of Chromium and Cyanide Rinsewater
and Addition of Rinse Tanks at Alameda NARF
Case No. 19

Alameda NARF operates two plating shops in which aircraft parts are plated. The principal metals plated are chromium, nickel and copper, with lesser amounts of cadmium, silver, tin and lead. Plating is carried out with 67 process tanks and 31 rinse tanks. A total of 20,000 gpd of water is used in the plating shop.

Previously, process tanks containing acid solutions were located next to alkaline cyanide tanks. These processes shared common rinse tanks and a common (and inadequate) ventilation system. This commingling of processes presented an occupational hazard as well as a hazardous waste disposal

problem. Acidification of the cyanide solution would have resulted in the evolution of hydrogen cyanide gas. This could have easily occurred through a common floor spill, where tanks were not segregated by a floor berm. It is also quite difficult to treat cyanide and other metal plating wastes once they have mixed. Segregation of acid and cyanide rinsewaters was recommended to optimize treatment.

In one of the plating shops (Building 360), plating lines were separated into rows of acid and cyanide plating lines, and the ventilation system was improved. In the other shop (Building 5), acid and cyanide tanks were relocated to opposite sides of a concrete wall, and additional containment dikes were constructed. These changes have significantly reduced the incidence of acid and cyanide mixing, although some mixing still occurs.

A consultant (15) recommended that a two-stage alkaline chlorine cyanide oxidation system be installed to treat wastewater containing cyanide. Due to time and cost constraints, a single-stage alkaline chlorination system is being installed, to partially oxidize cyanide to cyanate.

5.4.9 Conversion to Countercurrent and Conductivity Controlled Rinse at Alameda NARF Case No. 20

A description of the plating facilities at Alameda NARF is presented in section 5.4.8 of this report.

A consultant recommended that countercurrent and conductivity controlled rinsing be installed at these plating shops to reduce the generation of wastewater (15). Countercurrent rinsing was not adopted due to space limitations in the present facilities. Conductivity rinse controllers were not added because of reported operational and maintenance problems experienced by personnel at other DOD facilities that have installed them (6).

If a new combined plating shop is built to replace the two existing facilities, countercurrent rinsing is planned to be incorporated in the design. Developmental work is being carried out in cooperation with Naval Civil Engineering Laboratory (NCEL), Port Hueneme, to evaluate the effectiveness of electrolytic recovery of cadmium from rinsewater using equipment supplied by AgMet Equipment Corp.

5.4.10 Modern Plating System at Watervliet Army Arsenal Case No. 23

Watervliet Army Arsenal, located in Watervliet, New York, operates one of the world's largest electroplating

facilities to plate thick-walled cannon parts for field ordinance and ship guns. It is one of the few cannon manufacturing facilities in the non-Communist world.

Four huge plating lines, installed by NAPCO of Terryville, Connecticut, are used to plate chromium, cadmium and copper, and for anodizing and phosphating. Plating is applied for corrosion protection and to increase wear resistance under battlefield conditions.

Approximately 27 percent of plating drag-out was recovered from the rinsewater. Rinsewater flow was conductivity controlled. Rinsewater effluent was pumped to evaporators in which it was concentrated then returned to the plating tanks.

The production of wastewater from the plating facility was estimated to be 61,500 gpd in 1982 (17). This waste was treated in an industrial waste treatment plant and directly discharged to a river. Concentrated solutions were batch treated or bled into the system for treatment.

Most of the information used in this review was obtained from a recent journal article about the facility (20). Additional information will be gathered during Phase 2.

5.4.11 Rinse and Bath Changes at Mare Island NSY. Case No. 31

Mare Island NSY operates a plating shop, in which ship and submarine parts, equipment, hardware and circuit boards are plated. The principal metals plated are cadmium, silver, chromium, nickel and copper, with lesser amounts of tin, gold, and lead. Plating is carried out with 65 process tanks and 15 rinse tanks.

At Mare Island NSY, plating related hazardous waste has been reduced by the use of controlled flow rinsing, and by maintaining plating bath chemistry to reduce the frequency of plating bath dumps. A total of 81,000 gpd of water was being used in the plating shop. Wastewater was reduced to about 60,000 gpd by manual control of rinsewater flow. No special rinse modifications have been used. Two counter-flow rinse tanks are a part of a special project, but they are not often used.

Approximately half of the waste flow from the plating shop consists of drainage from scrubbers on the acid and chromium exhaust ventilation systems. Problems have developed due to poor maintenance on these scrubbers resulting in them running dry. When placed back in service, the resulting high concentrations of chromium exceeded the capacity of the industrial treatment plant (50 ppm of chromium).

There is little motivation to reduce the waste discharge from the plating shop, since the industrial wastewater treatment plant was sized to handle the flow presently being produced. In fact, there is a concern that a reduction in flow might adversely affect the treatment plant operation by reducing the dilution of more concentrated wastes. The treatment plant produces about 300 cubic yards of hazardous sludge per year, approximately 60 percent of it the result of treating waste from the plating shop.

Plating baths are monitored by the chemistry department and maintained such that they last at least 3 years between dumping. When they are no longer serviceable, they are hauled offsite and disposed of by a contractor.

5.4.12 Water Layer Over Methylene Chloride on Tanks at Various NARF's
Case No. 32

One proposed modification was to place a water layer on top of methylene chloride tanks to reduce drag-out at NARF plating shops. The individual who submitted this modification for study is no longer associated with the Navy department from which this recommendation was submitted. None of the personnel at NARF plating shops solicited were familiar with this modification. It is therefore recommended that further evaluation of this case be discontinued.

5.4.13 Ion Vapor Deposition of Aluminum to Replace Cadmium Plating at Pensacola and North Island NARF's
Case No. 33

Corrosion resistance can be provided for steel parts by three methods: cadmium can be plated on the basis metal using wet plating baths; cadmium can be plated using vacuum deposition; or aluminum can be plated by Ion Vapor Deposition (IVD). Of the three methods, IVD of aluminum appears to be the most environmentally safe.

At Pensacola NARF, the first two systems are utilized to plate cadmium on steel parts. Electroplating is from a conventional cadmium cyanide bath. Vacuum deposition of cadmium is performed using a "VaccuCad" system. Plating is done inside an air-tight 2-1/2-foot diameter by 5-foot chamber, located in a vertical laminar flow clean room. Condensed cadmium vapor is filtered from the airstream prior to venting to the atmosphere. The filters are rinsed prior to disposal. Plating using this system is limited to small parts, due to the size of the chamber.

Personnel at the Pensacola NARF would like to switch to Ion Vapor Deposition of aluminum and thus eliminate the environmental problems associated with cadmium and cyanide.

Facilities Engineering had included an IVD unit in the budget, but this was cut. Current military specifications do not include IVD of aluminum as a replacement for cadmium plating. These specifications would have to be rewritten prior to adoption of IVD.

Personnel at the North Island NARF, located in San Diego, California, have been using IVD of aluminum for about 7 years, having procured one of the first commercially available systems. Because it was a developmental model, they experienced numerous problems with it. They have procured a more recent model which has been greatly improved over the earlier model.

The facility overhauls Navy fighter planes such as F-4's, F-14's and F-18's and helicopters such as H-46's and H-53's. Metal parts that are to be IVD'd with aluminum include landing gears, bolts and tail hooks. The F-18's, manufactured by McDonnell Douglas are being produced with all of their steel parts IVD'd with aluminum rather than cadmium plated.

Advantages cited for IVD include a higher useful temperature, improved throwing power, and better adhesion of the aluminum coating compared to cadmium. Parts which are cadmium plated require baking to prevent hydrogen embrittlement. Problems were encountered with oven temperatures not being carefully controlled resulting in parts being scrapped. Safer working conditions were cited as an advantage of IVD of aluminum. A few years ago, one individual was hospitalized following exposure to cadmium while cleaning the VacuCad chamber.

Facilities Engineering wants to replace all cadmium plating with the IVD-of-aluminum method. There is opposition by production personnel to complete conversion to IVD, since the process is more complex and requires more labor and skill than does cadmium plating. For this reason, parts are being evaluated on an individual basis for conversion to IVD aluminum coating.

5.5 References

- (1) Carpenter, Charles J., Test and Evaluation of the LICON Chrome Recovery unit at NARF Pensacola, Technical Note # 2845TN, NCEL, Port Hueneme, CA, January 1984.
- (2) Carpenter, Charles J., Initial Feasibility Report on Innovative Hard Chrome Process, Technical Memorandum # 71-85-02, NCEL, Port Hueneme, CA, October 1984.

- (3) Olah, N. J., & C. J. Carpenter, Economic Metal Recovery Potential at Navy Electroplating Facilities, NCEL, Port Hueneme, CA, May 1984.
- (4) LICON, Inc., Operating Instructions, Chrome Recovery System for US Navy-NARF Pensacola, Pensacola, FL, 1979.
- (5) CENTEC Corp., Initiation Decision Report; Treatment of Electroplating Wastes, Tech. Memorandum # 54-83-20CR, NCEL, Port Hueneme, CA, October 1983.
- (6) CENTEC Corp., Navy Electroplating Pollution Control Technology Assessment Manual, Report # CR-84.019, NCEL, Port Hueneme, CA, February 1984.
- (7) U.S. Environmental Protection Agency, Control and Treatment Alternatives for the Metal Finishing Industry, In-Plant Changes, EPA 625/8-82-008, January 1982.
- (8) Hartley, H. S., "Evaporative Recovery in Electroplating,, Proceedings of the First Annual Conference on Advanced Pollution Control for the Metal Finishing Industry," US EPA-600/8-78-010, 1978, pp. 86-91.
- (9) Lowenheim, Frederick A., Electroplating, McGraw Hill, 1978.
- (10) Chesler, P. G., Plating Waste Survey, Report 2374, U.S. Army Mobility Equipment and Development Command, Fort Belvoir, VA, November 1982.
- (11) Aldridge, James R., "A Better Heavy Metals Treatment Method," Metal Finishing, November 1984, pp. 51-55.
- (12) Moore, Gardner & Associates, Inc., Naval Shipyards Industrial Process and Waste Management Investigation, Navy-Wide Conclusions, Report to Naval Facilities Engineering Command under Contract N00025-80-C-0015, July 1983.
- (13) U.S. Environmental Protection Agency, Control and Treatment Technology for the Metal Finishing Industry, Ion Exchange, EPA 625/8-81-007, June 1981.
- (14) Higgins, Thomas E. and Stephen G. Termaath, "Treatment of Plating Wastewaters by Ferrous Reduction, Sulfide Precipitation, Coagulation and Upflow Filtration," Proceedings of the 36th Purdue Industrial Waste Conference, 1982. pp. 462-471.

- (15) Report by Post, Buckley, Schah and Jernigan on Industrial Waste Reduction and Treatment Needs at Alameda NARF.
- (16) Water Quality Engineering Special Study No. 32-24-0331-84, Metal Finishing Wastewater Pretreatment Plant Evaluation, Tobyhanna Army Depot, March 30 - April 6, 1983, Prepared for US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD, 1983.
- (17) Chesler, P. G., Plating Waste Survey, Report 2374, U.S. Army Mobility Equipment and Development Command, Fort Belvoir, VA, November, 1982.
- (18) Whang, J. S., D. Young and M. Pressman, "Design of Soluble Sulfide Precipitation System for Heavy Metals Removal," Proceedings 13th Mid-Atlantic Industrial Waste Conference, 1981. pp. 63-71.
- (19) Pressman, Maurice, Pilot Plant Demonstration of a Sulfide Precipitation Process for Metal-Finishing Wastewater Treatment, Report 2408, U.S. Army Belvoir Research & Development Center, Fort Belvoir, VA, May 1984.
- (20) "Mammoth New Plating Facility at Army's Watervliet Arsenal," Product Finishing, Vol. 48, No. 8, May 1984. p 66.

WDR93/06

**Recycle of Solvents
& Other Organic Fluids**

6 RECYCLE OF SOLVENTS AND OTHER ORGANIC FLUIDS

6.1 Process Description

There are numerous industrial processes which generate solvents and other organic fluids that could potentially be recycled. This investigation includes 10 case studies related to recycling solvents and other organic fluids, which can be broken down into five types of industrial processes; 1) general maintenance (metal cleaning and degreasing), 2) paint booth cleaning, 3) fuel flow meter calibration, 4) refrigeration systems, and 5) machining operations. In addition, there are numerous other industrial processes at DOD facilities which generate waste solvents and other organic fluids, including paint stripping, solvent degreasing in plating operations, the use of heat transfer fluids in electronic components, fuel tank purging, and painting. While these processes are covered in more detail in other sections of this report, they are included here in order to show the variety of operations using solvents and other organic fluids.

6.2 Magnitude of Problem

Solvents and other organic fluids have been used at every facility that has been contacted. They are used in substantial quantities throughout the three services' industrial operations. The cumulative annual volume of solvents and other organic fluids used by the facilities analyzed in this section of the report is estimated to be in excess of 1 million gallons.

The total volume generated by the three services is not known. However, one report concerning solvents and other organic fluid use at Naval Shipyards (NSY's) gives an indication of the overall magnitude of this hazardous waste problem. The average volume of waste solvents from painting operations at Naval Shipyards is estimated to be 14,000 gallons per year. This report estimates that the solvent disposal and replacement cost associated with epoxy paints to be \$30,000 per year (1983 dollars). For the eight NSY's, this amounts to 112,000 gallons per year of waste solvents and \$240,000 per year for replacement and disposal of epoxy paint solvent.

This report also discusses the use of trichlorotrifluoroethane (TCTFE) at NSY's. TCTFE is used to degrease parts and clean oxygen flasks on ships. The average NSY usage to degrease parts excluding shipboard flushing was 7,000 gallons per year, or 56,000 gallons per year for all eight NSY's. At a replacement cost of \$13 per gallon, this represents an annual cost of over \$600,000. This report estimated that 6,000 of the 7,000 gallons used annually

evaporates, leaving 1,000 gallons for disposal. In addition, TCTFE is used to clean high pressure flasks used for oxygen service. While no total volume estimate was included in the report, its use appears to be significant since 45,000 gallons of TCTFE were used on a single submarine flask cleaning job. This volume of TCTFE would cost \$585,000 to replace.

The report also discusses refrigerant use at NSY's. The architect/engineer estimated that existing refrigerant usage in 1983 for blowing down and flushing shipboard refrigeration systems to be 112,000 pounds per year for the eight NSY's. At an estimated cost of \$0.80 per pound, the annual replacement cost would be \$89,600.

The report estimates that there are 60 machines and grinders at each NSY which utilize water based coolant. Navy wide, approximately 13,600 gallons per year of coolant concentrate are used at an cost of \$68,000 (1983 dollars). This concentrate is typically mixed with water at a 20:1 ratio for use in the coolant system. About one half of the coolant is thought to be lost to evaporation and drag-out, leaving 136,000 gallons of wastewater containing emulsified oil for disposal (1).

Based on our existing information, it would appear that the generation of waste solvents and other organic fluids is one of the most significant hazardous waste problems in the three services today.

6.3 Proposed Modifications

Modifications to recycle solvents and other organic fluids usually involve the addition of a recovery system to the industrial process. Each of the case studies in this section use a unique recovery system.

Batch distillation was the most frequently used technology for organic liquid recycle. In its simplest form, batch distillation utilizes a still pot, a heat source and a condensor. The waste organic liquid mixture is loaded into the still pot, heat is applied to the contents, and as the mixture boils, organic vapors separate from the waste mixture, and pass overhead to a condensor. Cases No. 5, 7, 8, 24 and 39 propose batch distillation for recovery of organic fluids.

Repair of shipboard refrigeration systems has generally resulted in the existing charge and a flushing charge of refrigerant being blown off. One repair section took the initiative to design and build a refrigerant reprocessing unit from spare parts on hand (a "flushing rig"). While the referenced report did not provide details of the technology

involved in cleaning the refrigerant, it did state that refrigerant is continually cleansed during recirculation of a flushing charge. This eliminates the necessity of blowing off flushing charges. This rig reduces refrigerant consumption by 50 percent, which has the potential of saving \$45,000 per year Navywide and has eliminated postrepair work caused by inadequate flushing. This technology is the basis of the modifications proposed in cases No. 36 and 37.

Current Navy practice is to pretreat waste machine tool coolant (emulsified oils) in an oily-wastewater treatment plant. This effluent then passes to a biotreatment plant. Slugs of high chemical oxygen demand (COD) resulting from emulsified oils passing through the oily-wastewater treatment plant in the water phase, can upset biotreatment plants. Other problems associated with the usage of machine tool coolants are dermatitis and hydrogen sulfide odors, both resulting from coolant degradation. Generally, coolants have been disposed of because they produce unpleasant odors, rather than because of the loss of performance. Two suggestions for eliminating these problems have been made. First, to alleviate the upsets caused by high COD slugs, the waste could be treated in a batch chemical emulsion breaking system. The high COD would then be removed as an oil phase and disposed of under contract. Secondly, machine tool coolant can be recycled using an ALMCO (or equal) coolant reprocessing station. This system removes tramp oil, the contaminant that promotes anaerobic conditions and hydrogen sulfide production. It also settles and removes suspended materials cyclonically, and aerates the coolant. It is estimated that reprocessing would cut coolant consumption in half: a total of 144,000 gallons of waste oil per year for the eight NSY's. With Navywide capital costs estimated to be \$244,000 and minimum savings to be \$107,000, the payback would be 2 years. This technology is used in case No. 30 (1).

In addition to the modifications used in the case studies reported here, several other methods of reducing waste solvents and other organic fluids have been suggested. A study done for the Navy recommended that waste epoxy paint could be eliminated and that the solvent required for cleaning epoxy spraying equipment could be reduced by changing the method of application to a GRACO (or equal) plural component spray system. This equipment pumps the two epoxy components directly from their original containers, through a heater (to reduce viscosity), a static mixer, and a spray nozzle. The manufacturer claimed reduced labor costs, reduced chemical exposure risks, elimination of mixing errors and spills, and elimination of epoxy paint wastes. According to the report, these cost reductions could result in savings of \$270,000 per year for the Navy's eight NSY's. The report estimated that 80 of these units, costing

about \$10,000 each, would be required for the eight NSY's. These systems would have a one year payback period (1).

The Directorate of Maintenance at Warner Robins AFB has made process modifications in the past three years to reclaim FC-77 heat transfer fluid, aircraft purging fluid, and cooling oil (4).

FC-77 heat transfer fluid is used as a cooling fluid to prevent high temperature arcing in the electronic control systems of F-4 and F-5 aircraft. The fluid was previously reclaimed with a small still, a filter, and a dryer unit. The still could only recover one gallon per hour which consistently did not meet production requirements. Furthermore, the reclaimed FC-77 heat transfer fluid could only pass dielectric and ultraviolet laboratory tests 7 percent of the time.

Maintenance personnel contacted 3M Corporation, manufacturer of the fluids, for assistance in reclaiming the material. Personnel from 3M suggested that the heat transfer fluid be refined by first mixing acetone and water with the fluid, decanting the organic phase, and then passing the organic phase through a dessicant column to remove the water. This technique has proven to be very successful. Production output has been increased to 18 gallons per hour. The reclaimed fluid has favorably passed laboratory tests for ultraviolet transmittance, acidity and dielectric strength. According to maintenance personnel, it cost approximately \$2 per gallon to reclaim the fluid compared with a cost of \$260 per gallon to purchase new material. The process modification has resulted in savings in material and disposal costs of \$235,000 in FY 1982, \$342,000 in FY 1983, and \$396,000 in FY 1984.

One rather novel organic fluid recovery system was a solar energy distillation system designed and constructed by the Aircraft Engineering Section at Warner Robins AFB (4). This system separated aircraft purging fluid from JP-4 jet fuel. The Aircraft Division was required to remove all JP-4 fuel from aircraft prior to major repair work. Fuels were first drained from the aircraft fuel tanks. The remaining traces of fuel were then removed by passing purging fluid through the tanks. Contaminated purging fluid was placed into drums for disposal once the flash point was reduced to the point where the fluid became classified as a hazardous waste. In the modified system, contaminated purging fluid was pumped through tubes heated by solar panels. The purging fluid was separated from the JP-4 fuel by distillation. Both purging fluid and jet fuel were then reused. The solar recovery system resulted in yearly savings of \$170,000 due to an annual recovery of 30,000 gallons of purging fluid and 3,000 gallons of JP-4 jet fuel.

inally, ultrafiltration, a relatively new technology, has been proposed and implemented to recover waste organic liquids in several Japanese industrial systems. Ultrafiltration, like regular filtration, separates on the basis of the size of the particles. Ultrafiltration, however, typically has pore sizes that are on the order of 0.01 microns, about 1,000 times smaller than most suspended particles. The membranes, therefore, can separate not only suspended particulates from the solution, but can also separate the constituents in solution on the basis of molecular weight.

This is significant since many waste paint solvent solutions contain particulate paint pigments and dissolved polymers. The membrane used in the systems reported is a solvent-resistant polyamide which has a molecular weight cutoff of 1,000.

Ultrafiltration systems can be as simple as a feed tank, a recirculating pump, a back pressure control valve, and a permeate collection tank. Systems are operated in both batch and continuous modes.

Fouling of the membranes is the key operational problem. As the thickness of the fouling layer builds up, the flux through the membrane decreases. The thickness of this layer is controlled to a great extent by the recirculation rate. The flowing liquid provides a scouring action which helps to minimize the buildup.

Two case histories involving recovery of paint solvents were given. The first involved the reclamation of solvent at an automobile manufacturing plant. The waste solvent contained 14.3 percent nonvolatiles (10.3 percent dissolved polymers and 4 percent pigments). The dissolved polymers greatly reduced the flux through the membranes, and resulted in only a 50 percent recovery. Even with this relatively poor recovery, the system had a 5.3 month payback period.

The second system reclaimed solvent produced from a cleaning operation at a sheet metal paint shop. The fresh solvent was 60 percent aromatics, 30 percent methyl ethyl ketone, and 10 percent other ingredients. Typically, the waste contained 11 percent nonvolatiles (9 percent dissolved polymers and 2 percent pigments) and resulted in less fouling than the waste described in the first example. The ultrafiltration system was able to achieve a 75 percent recovery. The recovered solvent was free of pigments and contained only 3.1 percent polymer resin. Typically 1,000 gallons per month have been treated and have resulted in a cost savings of \$2,600 per month which could pay for the system in less than a year (6).

4 Case Studies

4.1 Solvent Recycle at Warner Robins AFB Case No. 4

Warner Robins Air Force Base, located in Macon, Georgia, is a government-owned, government-operated (GOGO) facility which employs over 25,000 people. The base, which was constructed in 1942, is an Air Force Logistics Command installation that has the mission of refurbishing and maintaining airlift aircraft, fighter aircraft, bomber aircraft, utility aircraft, remote control aircraft, helicopters and missiles. The base predominately repairs C-130 and C-141 transport planes, and F-15 fighter jets.

The Directorate of Maintenance, which employs approximately 1000 workers, has the responsibility to purchase, transport, and dispose of hazardous chemicals. In fiscal year (FY) 1983, the Directorate of Maintenance used 3,700 drums (5 gallons each) of chemicals plus a variety of smaller packaged chemicals for repair operations. Approximately 45 percent of the chemicals were either used in the process operation, evaporated into the atmosphere, or discharged with wastewater for treatment. The remaining material was collected in 55 gallon drums for disposal or recovery.

Prior to the passage of RCRA in 1980, drums of hazardous waste with no resale value were disposed of in a landfill located on the base. The leakage of hazardous chemicals from some of the drums contaminated the surrounding soil. Semiannually, a sale was initiated and buyers would purchase used solvents and other organic fluids for recycle and reuse. Since the passage of RCRA, the Defense Property Disposal Office (DPDO) has had sole responsibility for disposal and sale of hazardous wastes. Stringent RCRA regulations have discouraged buyers from purchasing used solvents and other organic fluids for recycling. Therefore, DPDO pays contractors from \$60 to \$100 per drum to dispose of hazardous waste in federally approved hazardous waste landfills. In order to minimize the volume of chemicals requiring disposal, a chemical reclamation program was initiated at Robins AFB in March of 1981.

In 1982, Robins AFB purchased a batch, atmospheric pressure still manufactured by Finish Engineering Corporation, for \$18,000. The still is used to reclaim trichloroethane, neon-113, and isopropanol. In 1983, the Directorate of Maintenance's Chemical Control Group distilled 227 drums of chemicals for a savings of \$81,000. O.H. Carstarphen, Solvent Reclaiming Engineer, estimated that in fiscal year 1984 the recycling of the three chemicals saved the base \$118,000 in virgin material and hazardous waste disposal costs. It cost only \$13 per drum to reclaim the used

ifferent manufacturers are typically incompatible, the old coolant must be removed from all machine tool sumps and disposed of before replacement with the new material. The Navy Public Works Center--Hazardous Waste Division transports unrecycled waste coolant to the industrial waste treatment plant for treatment and disposal. Waste coolant is considered a hazardous waste due to contamination with lead, cadmium, copper, nickel, and beryllium.

Machine Shop personnel have requested that Engineering and Materials Supply change purchasing policies so that only one type of water soluble coolant is purchased and used for an extended period of time. By purchasing a single type of coolant, substantial savings could be realized by recycling. Anascola is trying to negotiate one year contracts to maintain the same cooling fluid from a single supplier, but this change in purchasing policy has not yet been approved.

5 References

-) Moore, Gardner & Associates, Inc., Navy-Wide Conclusions, Naval Shipyards Industrial Process and Waste Management Investigation, Naval Facilities Engineering Command, July 1983.
-) Gardner Machinery Corporation, Vacuum Still Operation Manual, Charlotte, N.C.
-) Tapio, Glenn E., Captain, A Limited Test of Solvent Reclamation at an Air Force Base, AFESC/RDV, Tyndall Air Force Base, Panama City, FL, 1984.
-) Ivey, Patrick, Captain, and Carstarphen, O.H., Directorate of Maintenance Chemical Program, Warner Robins Air Logistics Center, Macon, Georgia, 1982.
-) Walker, Thomas J., Major, Gross, Randy L., Captain, and Jeter, Jack H., 1st Lieutenant, "Getting Rid of Hazardous Wastes - R&D Searches for Answers," The Military Engineer, October, 1984.
-) Isooka, Y, Imamura, Y, and Sakamoto, Y, "Recovery and Reuse of Organic Solvent Solutions," Metal Finishing, June 1984.
-) Johnson, J.C. and Wedmore, L.K., "Metal Cleaning by Vapor Degreasing," Metal Finishing, Vol. 81, No. 9, September 1983.

NR93/06

greaser TCE baths have never been dumped during normal operation or shutdown. Losses of TCE are due to drag-out, evaporation and waste still bottoms.

Still bottoms are automatically discharged to waste holding tanks. Still bottoms have typically contained 11 to 15 percent TCE, oils, greases, and dirt. This hazardous waste has been sent to a commercial contractor for treatment. Anniston has investigated if it would be cost-effective to recover TCE from still bottoms. It was determined that the still bottoms would have to contain 10 percent TCE before it would be economical to recover additional solvent.

4.10 Machine Tool Coolant Recycle at Pensacola NARF Case No. 30

The machine shop uses emulsions to cool work pieces during drilling, grinding, milling, and lathing. Concentrated coolant is diluted to a 4-percent concentration with deionized water. During use, the water-coolant mixture becomes contaminated with dirt, metal chips, oil and grease, after which it can be either cleaned and recycled or disposed of. At Pensacola the coolant in approximately 5 machine tools is changed every 2 to 4 weeks.

A centrifuge was purchased in 1980 to separate coolant from contaminants. Shortly after the centrifuge's purchase, the person responsible for implementing the coolant recycle system left Pensacola NARF, and the centrifuge was not installed at that time due to lack of interest. In the beginning of 1984, the centrifuge was finally installed and has since been operating sporadically.

Contaminated water soluble coolant is transferred from individual machine tool coolant to a general storage tank or recycle. Metals solids and dirt are removed by settling in the storage tank and in a sump pit and along with training. Once a sufficient quantity has been collected, waste coolant is pumped from the storage tank to the centrifuge, where oil is separated from the water-based cooling emulsion. Recycled coolant is transported back to individual machine tool sumps. Waste oils and solids are transferred to the Defense Property Disposal Office (DPDO) for resale, treatment, or disposal.

The Machine Shop has only recycled limited quantities of coolant since most coolant purchased cannot be treated by the centrifuge. The centrifuge will only perform an oil-water separation on water soluble coolants, such as Trimsol and Simcool. New supplies, which are purchased from the low bidder, are frequently for an oil soluble coolant which cannot be recycled by the centrifuge. Since coolants from

armored vehicles. Approximately 700 tanks are reconditioned at the facility each year.

Reconditioning consists of complete disassembly of the tanks and dismantling of their components. Paint, rust, and dirt are removed from these components prior to manufacturing. Paint is removed by sand blasting or stripped using organic solvents or alkaline strippers. Greases and oils are removed using solvent vapor degreasers, followed by alkaline cleaners. Rust and oxide films are removed by sand blasting and acid pickling.

Solvent vapor degreasing is an effective and economical process for cleaning oils and greases from metallic and other suitable surfaces. Trichloroethylene (TCE) is commonly used in vapor degreasers for the removal of semi-cured varnish or paint films, heavy rosins and buffing compounds (7). 1,1,1-trichloroethane is used to clean printed circuit boards, electronic components and electrical motors. Methylene chloride and perchloroethylene are also used in some vapor degreasing operations. In general practice, 1,1,1-trichloroethane is the most widely used solvent today due to its economical cost, low solvent consumption, and low energy requirements. This solvent also has a higher acceptable OSHA vapor exposure limit and is exempt from air pollution regulations in most states (7). The other solvents are used when their special properties (e.g., lower or higher boiling point) are required for specific cleaning applications.

Approximately 15 to 20 TCE vapor degreasers are being used at Anniston Army Depot. Personnel at Anniston previously evaluated the use of 1,1,1-trichloroethane as a replacement for TCE as a vapor degreaser. One tank was operated using 1,1,1-trichloroethane for a 6-month trial period. 1,1,1-trichloroethane failed to clean parts as well as TCE, and its use was discontinued.

All of Anniston's vapor degreasing tanks are equipped with a distillation solvent recovery system. The stills recover TCE from the solvent-oil mixture for reuse in the degreasers. Most stills at Anniston are manufactured by Detrex Corporation. The stills operate continuously when the vapor degreasers are in operation. Normally degreasers are operated 8 hours per day, 5 days per week. Dirty solvent is fed from a degreaser boiling sump through a water separator to the recovery still. The steam-heated stills have the capacity to recycle 20 gal/hr of TCE.

Anniston Army Depot has had no problems in the operation and maintenance of the distillation units. Twice a year during shutdown, the vapor degreasers and stills are taken out of service for cleaning and general maintenance. Vapor

enabled it to be recirculated through a repaired unit. As a result of this system being used, there was less concern about minimizing flushing time and post-repair rework of refrigeration units has been eliminated. Refrigerant use has been cut in half at this facility (1).

Three management aspects of this project seem to have contributed significantly to its success. First, the refrigeration repair section obviously had a concern about the practice of blowing off the once-through refrigerant flush. Someone in the group came up with an idea to eliminate the blowoff and they made it work. Secondly, the system was built by the people directly involved with the system, and was thus easy for them to understand and operate. Finally, the system did not require additional resources, either in capital expenditures or in manpower assignments.

6.4.8 Refrigerant Reuse at Norfolk NSY Case No. 37

Refrigerant flushing of repaired shipboard refrigeration systems at Norfolk has been conducted in a manner similar to that described in Case No. 36 (Section 6.4.7). A proposal was made to construct a refrigerant reprocessing unit that would be a duplicate of the system used at Charleston. However, this proposal was never implemented.

The lack of success here, compared to the success at Charleston, serves to emphasize the importance of the concern and involvement of the operational personnel. The stated reason for the process not being implemented was a lack of manpower. The Charleston repair section, however, managed to design and construct the unit from spare parts in their spare time with no additional manpower (see Case No. 36, Section 6.4.7). The fact that the people who would operate the system in Norfolk had not participated in its development and did not have a stake in its success could also have contributed to its failure. This new reprocessing rig was not their idea and they apparently did not exhibit concern about the discharge of refrigerant. Without a champion for this innovative and cost effective technology at Norfolk, it apparently died.

6.4.9 Recycle of TCE from Vapor Degreasers at Anniston Army Depot Case No. 39

Anniston Army Depot, constructed in 1941, is a government-owned, government-operated (GOGO) industrial facility, employing approximately 4,500 people. The principle mission of the facility is to recondition used tanks and other

<u>ORGANIC</u>	<u>USAGE (GALLONS)</u>
Stoddard Type II	59,371
1,1,1-Trichloroethane	48,500
Methyl Ethyl Ketone	24,100
Kerosene	9,500
Dichloromethane	2,400
Toluene	2,200
Freon	23,900
Naphtha	600
BNB 6220 (proprietary solvent)	3,500

Pensacola has three or four stills attached to vapor degreasers for the recovery of cleaning solvent. The stills were originally purchased and installed for the recycling of trichloroethylene (TCE). Pensacola suspended the solvent redistillation operation after switching from TCE to 1,1,1-trichloroethane. According to Detrex Corporation, a leading manufacturer of vapor degreasing stills, the units could easily be adjusted for the recovery of 1,1,1-trichloroethane. Pensacola personnel have not perceived a need to reduce hazardous waste by operating the stills for the recovery of 1,1,1-trichloroethane.

Pensacola NARF have also purchased a few small portable stills for the recovery of Freon. These stills have only been used when there has been a shortage of fresh, virgin material.

There are no plans to permanently operate either the vapor degreasing stills or the Freon stills in the future.

6.4.7 Refrigerant Reuse at Charleston NSY Case No. 36

Shipboard refrigeration units have been flushed with refrigerant after repair in order to remove any impurities that remain in the system from the repair operations. Flushing refrigerant has generally been blown off to the atmosphere. In the past, operating personnel have tried to minimize the amount of refrigerant used in the flushing operation and ultimately blown off to the atmosphere. Often times, however, the flushing was found to be inadequate and the system required a second cleaning with refrigerant.

The refrigeration repair section at the Charleston NSY became concerned with this situation, and devised and constructed a "flushing rig" from spare parts that were available. This flushing rig was a portable refrigerant reprocessing unit. Although the technology that this rig employed was not disclosed in the information gathered, the system cleaned the impurities out of the refrigerant, which

In the past, all of the waste calibration fluid was shipped by DPDO to Brookhaven National Laboratories for use as boiler fuel at no cost to Kelly AFB.

In April 1984, Kelly AFB contracted with a local solvent reprocessing firm to pick up the used organic fluids, process them in a distillation system, and return them to the Base, where they were analyzed and either reused or returned to the contractor for additional processing. The original contract was for the contractor to reprocess 100,000 gallons of organic fluid over one year at a cost of \$0.85 per gallon. At the time the contract was issued, Type II Calibration Fluid could be purchased for \$1.89 per gallon. At this writing, in December 1984, the cost of fresh solvent has dropped to \$1.29 per gallon, thus diminishing the incentive for maintaining the contracted system of reclamation.

Results have been poor, but inconclusive to date. The first few batches of solvent failed to meet specifications. After discovering that failure was caused by a lack of a corrosion inhibitor, the contractor simply added the appropriate amount and few problems have been encountered since. The contractor also reprocessed perchloroethylene. The results have been poor and has resulted in only a 50-percent recovery factor. Only 10,000 gallons of solvents were reclaimed in the first 8 months of the contract, whereas, the proportionate amount of the contracted volume would be about 70,000 gallons. The contract is currently being renegotiated, to extend the period of performance.

This method of recovering organic fluids is still in the process of being tested and analyzed. While it appears that several problems still exist with the contractor's recovery operation, this case study cannot be judged to be either a failure or a success at this time.

6.4.6 Solvent Recovery at Pensacola NARF Case No. 29

All waste solvents at Pensacola NARF are either dumped to the industrial wastewater system, which does not provide treatment for volatile organics, or they are shipped under manifest, by DPDO, for disposal offsite. To our knowledge, no solvents are currently being recovered at this facility.

Use of organic fluids was estimated to be as follows for 1983:

The indirect heating employed by this system eliminates the wastewater generated by direct steam heated stills, and the resultant problems of treatment and disposal.

A certain amount of organic vapors were being pulled through the vacuum pump and vented to the atmosphere. The amount, flammability, and toxicity of organics discharged should be considered. Also, the long term effect of these vapors on the vacuum pump should be evaluated.

This solvent recovery operation had three key elements which combined to make it a success; personal dedication of a production representative, a technically elegant system that was easy to operate, and a system that was located where the waste was generated. Jake Coulter, the Paint Shop Foreman, has been the champion of this solvent recovery operation. Being a fisherman, he became concerned about past improper disposal practices. As a result, when he came into a position where he had control over the disposal practices of the paint shop, he made it his business to implement a solvent recovery process. He has wanted it to work, and it appears to have been a great success. The second element was the straightforward, uncomplicated operation of a technically innovative system. Once the system was set up, which took approximately 15 minutes, one button started the system which could then run unattended.

6.4.5 Solvent Recovery at Kelly AFB Case No. 24

Two projects involving organic fluid recycling were reported for Kelly AFB. One project involved recycling vapor degreaser solvent, and the second project involved contracted reclamation of calibration fluid and perchloroethylene.

Vapor degreasing solvent was being recycled using a batch still system. The operator of the still died about 5 years ago and the position was not refilled. The system has been abandoned. Although there was a paucity of information about this project, it appears to have been successful while it was operational.

Calibration Fluid for Aircraft Fuel System Components, Type II, Military Specification No. C-7024, is a form of Stoddard solvent used as a substitute for jet fuels to calibrate fuel system components, such as fuel flow sensors. At Kelly AFB, approximately 350,000 gallons of Type II Calibrating Fluid have been used annually, at a cost (in 1984) of \$1.29 per gallon.

waste organic fluids were disposed of by DPDO at a reported cost of \$7.80 per gallon.

A nonfractionating, batch still, model LS-15V manufactured by Finish Engineering, Erie, Pennsylvania, was used at this facility. This model was designed to recover 15 gallons of solvent per shift of operation (i.e., one full charge of the still pot). The system employed an electrically heated pot with a residue collection pan, a water cooled shell and tube condenser, a reclaimed solvent collection tank and an electric vacuum pump. The system was designed to recover organic fluids with boiling points in the range of 100°F to 320°F without using the vacuum system. The vacuum system, which produced a vacuum of 25 inches of mercury during operations, was designed to recover organic fluids with boiling points up to 500°F.

The system produced a solid residue in the still pot's residue collection pan. The collection pan was then removed and the residue was emptied into a container for disposal. The uninstalled cost of this system was approximately \$9,000. The same system without the vacuum system option cost \$5,000.

The day of the site visit was the first day of system operation with the vacuum accessory. Mineral spirits were distilled under vacuum. A teflon gasket on the still pot deformed, apparently as a result of the vacuum. Jake Coulter, the Paint Shop Foreman, removed the gasket and was able to maintain 22 inches of vacuum in the system. Dry paint solids remained in the collection pan after the cycle was completed. These solids were easily removed for disposal.

The system recovered approximately 13 gallons of solvent from a 15-gallon charge of waste solvent for an 85-percent recovery.

The system had been used successfully without the vacuum system to recover organic fluids boiling below 320°F. Jake Coulter reported recovering more than 50 percent of the waste solvent at a cost of about \$0.05 per gallon operating at atmospheric pressure.

This solvent recovery operation has experienced continued success since the site visit. The solvent recovery system, as installed, was expected to continue recovering methyl isobutyl ketone, methyl ethyl ketone, epoxy thinners and mineral spirits, provided solvent segregation practices are maintained.

Indianapolis, Indiana, was installed to reclaim heptane from the underground waste storage tank. The system used live steam injected directly into the pot to heat the waste organic fluid mixture. Distillate passed through a demister into a watercooled condenser. This system produced a two phase (water and organic) condensate which was separated in a decanter. The system was designed to produce up to 50 gallons per hour of distillate.

One batch of waste organic fluid was processed through the still three times in an attempt to meet specifications for calibration fluid. This reprocessed organic fluid failed to meet three specifications for Type II calibrating fluid. The initial boiling point was 264°F versus a minimum acceptable boiling point of 300°F; the flash point was 87°F versus a minimum of 100°F; and the sample contained 1.2 mg/l of sediment versus a maximum limit of 1.0 mg/l. Waste organic fluid was distilled at a rate of 12 gallons per hour during this test.

The still has not been used since the initial attempts to recover heptane for calibration fluid in February, 1983. Although the reprocessed heptane failed to meet specifications, several of the contributory causes were unrelated to the equipment. The reprocessed heptane probably failed to meet the initial boiling point and the flash point specifications because lighter organic fluids were mixed with the waste heptane. Since this still could not fractionate the components, everything that vaporized below the cutoff temperature was distilled and combined. Segregation of the waste heptane from the other organic fluids could alleviate these off-spec properties. The sediment level, which was slightly above the specification, may be the result of improper cleaning of the still and associated piping prior to startup.

The use of direct steam injection produced an undesirable secondary wastewater stream that was saturated with the recovered organic fluids. This waste stream could be eliminated by using an indirect method of heating the waste organic fluid mixture in the still pot.

6.4.4 Solvent Recovery at Norfolk NSY Case No. 8

The modification at Norfolk NSY involved recovery of solvent generated at a paint shop. Numerous waste solvents including mineral spirits, ketones, and epoxy thinners containing paint pigments were generated in the paint shop during cleaning operations. Approximately 15 gallons per day of waste solvents were being generated at this one paint shop. Historically, the waste mineral spirits and other

users which expressed an interest in the free material. Maintenance personnel at the tire shop were pleased with the quality of the recycled Stoddard solvent. They noticed, however, that the recycled material took longer to dry than when fresh Stoddard solvent was used.

No major problems were usually encountered during operations. During two runs, however, the still was shut down briefly because the waste Stoddard solvent was contaminated with methyl ethyl ketone and hydraulic fluid. A normal batch run required a single operator for eight hours. Two-man crews were used for safety and training.

The system had one inconvenient design flaw. Since the still sat on grade, the waste bottoms could not flow directly into a 55-gallon drum. The waste had to be emptied into a 5-gallon can and then transferred to a drum. This problem could have been alleviated if the still had been elevated 3 feet.

Operation of the still was discontinued because of its limited use, off-spec product quality and resultant poor economic performance. Plans have been made to dispose of the still. Consideration was being given to a suggestion that the still be given to Robins AFB in Macon, Georgia, to supplement their existing solvent recovery unit (see Case No. 4, Section 6.4.1).

6.4.3 Heptane Recovery at Norfolk NARF Case No. 7

Heptane has been used as a calibrating fluid for aircraft fuel flow sensors at the Norfolk Naval Air Rework Facility. Heptane was used as a substitute for jet fuels JP-4 and JP-5 because it exhibited properties that simulated the jet fuel yet had a more consistent composition from batch to batch than jet fuel. It has been of vital importance to maintain this consistency in order to calibrate the fuel flow sensor with a known standard, therefore, stringent specifications exist for this calibration fluid. About 25,000 gallons of heptane have been used at this facility each year.

Heptane was stored in underground tanks and recirculated through test stands. Waste heptane and other organic fluids used in this building were mixed and stored in an underground waste storage tank. This mixture of waste organic fluids was sold to Brookhaven National Laboratories for boiler fuel. An onsite waste blending facility would not accept this waste because its flash point was below acceptable limits.

A nonfractionating, batch, atmospheric distillation system, manufactured by Solvent Purification Systems of

primarily as a result of a dramatic drop in the price of fresh Stoddard solvent from \$4.51 per gallon to \$1.90 per gallon over the same period (5). To date, only 4,500 gallons of Stoddard solvent have been reclaimed, resulting in a cost savings of approximately \$7,000.

The poor economic performance was the result of the system being under-utilized. The quantities of solvent recycled were less than anticipated due to the following reasons:

- (1) Many of the original users switched to a different cleaning solution.
- (2) It was difficult to collect, transport, and store the waste Stoddard solvent that was being generated in the numerous small shops. It was easier for the maintenance personnel to dump the waste solvent into the sanitary sewer or into a common slop drum for disposal.

The poor success of the collection system may have been the result of not having both the involvement and commitment of the operational personnel. The concept was developed by an outside group and implemented as a research project. In addition, management's commitment to the success of the project was not as evident as for a similar system implemented at Warner Robins AFB (see Case No. 4, Section 6.4.1).

Of the 19 shops that used Stoddard solvent in 1981, only the tire shop actively collected and stored waste solvent for recycle. This shop used two 300-gallon dip tanks that contained Type II PD-680 Stoddard solvent. The cleaning solution removed carbon, grease, and grit from aircraft wheel bearings. Every four months, the spent Stoddard solvent was discharged into ten 55-gallon drums. The waste solvent in the drums were then pumped to the still holding tank for recycling.

The still was operated nine times since 1981; approximately one day every four months. An average of 506 gallons of solvent were recycled at a recovery rate of 97 percent during each of the nine runs. Samples of the recycled solvent were analyzed and generally failed to meet specifications because of an undetected internal still leak and a buildup of iron oxide in the system during periods of nonuse.

Since the recycled solvent did not meet specifications, it could not be accepted by the base supply department for distribution and reuse. Most of the recycled solvent was, however, reused in the tire shop, which did not require solvent that met the specification. Some of the solvent bypassed the supply department and was sent directly to

materials, such as PD-680 dry cleaning solvent and silicone damping fluid, that cannot be reclaimed with the existing still. The new still would also be used to reclaim materials, such as paint thinners (e.g. methyl ethyl ketone and toluene) and coolanol 25R fluid, that were not being recovered because of inadequate capacity. According to maintenance personnel, the total potential savings in material costs and disposal costs for the new still is expected to be \$315,000 per year.

In addition, the Directorate of Maintenance was examining the possibility of obtaining a vacuum still from Tyndall AFB that was out of service (see Case No. 5).

6.4.2 Solvent Recycle at Tyndall AFB Case No. 5

At Tyndall Air Force Base, Panama City, Florida, solvents have been used in the general maintenance of jet aircraft and motor vehicles. In 1981, the Air Force Engineering and Services Laboratory initiated a research project at Tyndall to determine if solvents could be economically recycled on the base. Stoddard solvent was selected as the organic liquid to be recovered in this project. Stoddard solvent (Military Specification PD-680) is an aliphatic petroleum distillate and was used primarily for metal cleaning and degreasing at Tyndall Air Force Base. In 1981, it was estimated that approximately 13,000 gallons of Stoddard solvent were being used per year at a total of 19 different shops, making it the most used solvent at Tyndall.

The solvent recovery system employed a vacuum still system manufactured by Gardner Machinery, Charlotte, North Carolina. This system had a rated overhead capacity of 200 to 225 gallons of solvent per hour, and was designed to process Stoddard solvent, 140° F solvent, light D.C. naphtha, VM & P naphtha, mineral spirits, and petroleum spirits.

The system at Tyndall was heated indirectly with steam, which was generated in an electrically heated boiler. This system could generate saturated steam at a pressure of up to 100 psig.

Vapors were condensed in a water-cooled condensor. The liquid then passed through a moisture absorption tank filled with cotton rags, and finally to a clean solvent storage tank or a 55 gallon drum.

The economics of this system have been poor. The solvent recovery system cost approximately \$50,000 to purchase and install. The cost savings dropped from \$3.72 per gallon of solvent recovered in 1982 to \$1.44 per gallon in 1983,

other impurities out of the waste slop cans and drums. Segregation of the waste liquids is necessary in order to maintain the usefulness of the recovered organic fluids. For example, two common paint thinners, methyl ethyl ketone and toluene, could easily be mixed together in the waste slop drums in the painting shop. However, if this occurs, the mixture could not be effectively separated by single-stage batch distillation because their boiling points are close together.

Management's commitment to the organic fluid recovery operation has been very strong, as demonstrated by the facilities and manpower dedicated to the operation of the system. Waste chemicals at Robins AFB are collected at 30 different areas by the Chemical Control Group. These collection areas have controlled access, are covered, and are on diked concrete pads. The areas are used for both the dispensing of fresh solvents from drums and the collection of waste solvents in separate, labelled drums. Site managers are responsible for the segregation of wastes at the different sources. The Chemical Control Group, which consists of ten people, is responsible for performing the following tasks: sampling all drums, redistilling Freon, trichloroethane, and isopropanol wastes, and transporting the reclaimed materials back to the original destination. In addition to the Chemical Control Group, analytical chemists are required to perform two sets of analyses for each drum of waste. First, as it is received the contents must be analyzed to confirm the labelling. After each distillation run the recovered solvent is also analyzed to ensure that it meets appropriate specifications.

Hazardous wastes that cannot be reclaimed are transported to the DPDO storage facility located on the base for sale, donation, or ultimate disposal.

One additional management tool implemented at Robins AFB to educate base personnel about hazardous wastes has helped the reclamation program work. The Directorate of Maintenance developed a course entitled "Storage, Handling, and Disposal of Industrial Chemicals", which is attended by all personnel who store, handle, use and/or dispose of industrial chemicals. Scope of this training includes industrial materials terminology, personnel protective equipment, hazard identification systems, emergency procedures, and industrial waste collection and disposal.

Robins AFB recently purchased a second still from Finish, Inc. for \$97,000 to supplement their existing unit. By using a vacuum, this new system will have the capability of distilling organic fluids which have atmospheric boiling points up to 500° F while maintaining a 300° F limit in the still's pot. This new still is to be used to recover

chemicals, whereas disposal of the chemicals and repurchase of new materials would have cost from \$250 to \$500 per drum.

The organic fluid recovery system consists of a single-stage batch still, a water separator, and an electrically powered steam generator. The still can operate up to a temperature of 300° F in the pot and can reclaim organic fluids at a rate of up to 55 gallons per hour. Freon and isopropanol were processed at a rate of approximately 50 gallons per hour and trichloroethane was processed at a rate of 35 to 40 gallons per hour. Recovery efficiency for isopropanol and Freon-113 is approximately 95 percent. The recovery efficiency for trichloroethane is only 70 percent since the used material contains nonvolatile waxes, dirt and greases that are removed from metal parts during degreasing operations.

The Finish still has been easy and inexpensive to operate and maintain. Some problems were initially encountered with a feed pump when recycling Freon, but these problems have been solved.

Freon-113 is predominately used in the Gyro Shop and in the Aircraft Sealant Operation. The reclaimed Freon does not meet Type I military specifications; however, it does meet Type II military specifications and is consequently used for initial cleaning. New, virgin material is used for final assembly cleaning operations which require Type I Freon.

Presently, 584 drums of degreasing solvents are used annually by the Directorate of Maintenance. Trichloroethane is recycled since it is the predominate solvent used at Robins. Approximately 175 drums per year of trichloroethane are currently being reclaimed for reuse in vapor degreasing tanks located in the plating shop. Laboratory tests of the reclaimed trichloroethane have indicated that the material meets military specifications. Since July 1982, the Directorate of Maintenance estimated that recovery of waste trichloroethane has amounted to a savings of approximately \$79,000.

Isopropanol is used in the Airborne Electronic Division for the cleaning of electronic parts. The alcohol was previously discarded when the solution became contaminated with oils and dirt. Isopropanol is currently being reclaimed by the organic fluid recovery system resulting in a savings of \$16,200 in FY 1983 and \$18,500 in FY 1984. A 5-micron filter was installed in the discharge line for removal of fine metal particles which were carried over with the alcohol vapors. The reclaimed alcohol had a purity of 99.8 percent.

Recycling at Robins has been successful because personnel prevent the mixing of wastes and keep excessive water and

Explosives Manufacturing

7 EXPLOSIVES MANUFACTURING

7.1 Process Description

Nitrocellulose, a conventional propellant, is formed by treating wood pulp, or cellulose, with a mixture of nitric acid and sulfuric acid. Nitrocellulose, a cotton-like solid or white amorphous powder, is extremely reactive in its dry state. When wet, however, nitrocellulose is an unreactive, white, watery liquid.

Nitric oxide (NO) and nitrogen dioxide (NO_2) are unwanted by-products generated in the manufacturing of nitrocellulose. Nitric oxides (NO_x) are criteria air pollutants. However, they are not listed as hazardous substances by the EPA. The removal of NO_x is the subject of Case Studies No. 13 and 25.

Manufacture of trinitrotoluene (TNT) takes place in three stages: nitration, purification, and finishing. During nitration, toluene is converted to TNT by reaction with a mixture of nitric and sulfuric acids. During purification, liquified crude TNT is washed with fresh water to remove any remaining acids. Spent TNT wash water is known as "yellow water." TNT is further washed with a sodium sulfite (sellite) solution using a two stage countercurrent extraction system. Spent sellite solution (known as "red water") is usually incinerated. During finishing, the TNT-water emulsion is dried. Dust and fumes in the production area are passed through a venturi scrubber. Scrubber blowdown is pink as a result of nitro bodies, and is known as pink water.

Red, yellow and pink waters are hazardous wastes. Treatment of red, yellow and pink waters is the subject of Case Studies No. 14 and 15.

7.2 Magnitude of Problem

Uncontrolled, NO_x concentrations in the exhaust gases have ranged from 2,000 to 3,500 ppm. The volume of this exhaust gas generated per ton of TNT produced is not known as of this writing.

Approximately 400 pounds of red, yellow, and pink water are generated for every ton of TNT produced (10). At Radford Army Ammunition Plant, approximately one million pounds of TNT are produced per month, yielding about 2.5 million gallons of red, yellow, and pink water. Milan Army Ammunition Plant produces about one million gallons per month of red, yellow, and pink water.

7.3 Proposed Modification

Modifications put forth to reduce nitrogen oxide emissions generally involve an end-of-pipe, add-on treatment process to convert NO_x to nitrogen gas. This conversion is carried out in numerous processes. Several involve high temperature gas phase reactions with reducing gases such as methane and/or hydrogen. Catalysts are often added to enhance the rate of reaction. Other processes utilize different reactants, such as an aqueous urea scrubbing solution, or a mixture of molten nitrate and hydroxide.

Two processes, however, convert NO_x to nitric acid instead of nitrogen gas. The first process reacts nitric oxide (NO) and nitrogen dioxide NO_2 to nitric acid and absorbs the acid in water. This process² has generally been carried out in a countercurrent aqueous bubble cap absorption column. Conversion of NO_2 to nitric acid proceeds relatively rapidly. The rate limiting step in this process is the reaction of NO to NO_2 . The second process also utilizes absorption; however,² the rate limiting reaction of NO to NO_2 is catalyzed by molecular sieves in a secondary piece of equipment. The absorption system tail gas is compressed, cooled, dried, and passed through a column packed with molecular sieves. The sieves purportedly adsorb NO that was not reacted in the absorption system and catalyzes the reaction to NO_2 . During periodic regeneration of the molecular sieves with hot gas, NO_2 is driven off of the sieves and into the gas stream. Regenerant gas is then passed through an absorption column where the NO_2 is converted to nitric acid.

TNT manufacturing facilities typically incinerate yellow, pink, and red waters. To prepare the wastes for incineration, the yellow water is initially neutralized and combined with the pink water. The combined wastewater is concentrated by evaporation, mixed with red water and fed to an incinerator.

Since the late 1950's, activated carbon adsorption has been shown to be an effective method for removal of nitrocompounds from ammunition wastewaters. The spent carbon is considered to be a hazardous waste because of its reactivity.

In 1984, a pilot study was conducted at Milan Army Ammunition Plant to determine the effectiveness of further removal of nitrocompounds from a carbon adsorption system effluent by recirculating the wastewater through an atmospheric spray system in a lagoon. The spray system was operated for periods between 60 and 72 hours for each batch of wastewater treated. Average nitrocompound concentrations were reduced from 69 micrograms per liter to 7.1 micrograms per liter in effluent from the spray lagoon. Solar ultraviolet radiation

enhanced removal of nitro bodies. A compound known as RDX (hexahydro-1,3,5-trinitro-s-triazine) was not effectively treated by this process and was the primary nitro body remaining in treated effluent. The pilot system has been dismantled; however, further research is being conducted into effective removal methods for RDX (5).

7.4 Case Studies

7.4.1 Molecular Sieves at Radford Army Ammunition Plant Case No. 13

Radford Army Ammunition Plant, constructed in 1941, is a government-owned, contractor-operated (GOCO) facility employing over 4,000 people to produce over 5 million pounds of propellant and over 1 million pounds of TNT per month. The facility is operated by Hercules, Incorporated.

Two parallel molecular sieve gas adsorption units, designed by the Army Corps of Engineers, were installed at the Radford Plant to reduce the atmospheric emissions of nitrogen oxides (NO_x), which are produced in the manufacturing process for nitrocellulose. Nitrogen oxides removed from the air stream are converted to dilute nitric acid.

Without treatment, NO_x concentrations ranged from 2,000 to 3,500 ppm. According to James Morris of Hercules, the molecular sieve system was selected since it was the only technology that could meet an anticipated EPA NO_x emission standard of 200 ppm. However, EPA final regulations were never promulgated. Instead, the facility is required to meet a less stringent state opacity standard of 20 percent. Molecular sieves have consistently reduced NO_x concentrations to less than 50 ppm, easily meeting the opacity standard.

The molecular sieve adsorption system consisted of the following components: high speed gas compressor, heat exchanger, mist eliminator, and two parallel adsorption columns packed with molecular sieves. The compressor increased the pressure of the gas stream containing NO_x . The high pressure, high temperature gas then passed through a heat exchanger which lowered the temperature. Dilute nitric acid droplets were then removed by a mist eliminator. Solidification of the molecular sieve media has occurred when liquid was not adequately removed. NO_x adsorbed on molecular sieves as the dry gas passed through two adsorption columns. The clean gas was vented to the atmosphere. Molecular sieves were regenerated by passing hot air through the bed at atmospheric pressure. During regeneration, off gas passed through a counter-current bubble-cap absorption

column where NO_x was absorbed into an aqueous stream and converted to nitric acid.

The molecular sieve system has experienced considerable maintenance problems. During the past year, the units have been shut down for repairs approximately 20 percent of the time due to mechanical failures. Repairs have cost approximately \$500,000 during four years of operation. The high speed rotary compressor had many parts that could fail, which resulted in high maintenance costs. For example, it recently cost \$105,000 to perform major repairs on the shaft and ball bearings. An instrumentation and control system was used to measure and record regeneration gas flow, differential pressure across the mist eliminator, main gas flow, and regenerant gas pressure and temperature. According to Morris, these control units were also costly to repair and maintain. Long term operation and maintenance was further complicated by the fact that Union Carbide, the sole supplier of molecular sieves for the process, no longer manufactures them.

Despite maintenance problems, the molecular sieve system was easy to operate. The system efficiently removed NO_x and recovered nitric acid from the air stream. However, the weak nitric acid recovered during regeneration was of insufficient volume and concentration for its value to significantly reduce the overall cost of operating the molecular sieve system. The system required close supervision since the units were to be shut down immediately after a mechanical failure to prevent further maintenance problems.

According to Radford personnel, the molecular sieve system had two design flaws which significantly affected operation. First, some of the original materials of construction were incompatible with the corrosive environment. Experience has shown that materials which are exposed to the acidic environment of this process should be constructed of corrosion resistant materials such as stainless steel. The construction specifications, however, did not require stainless steel for the molecular sieve vessel sleeves. Consequently, during the initial startup, one of the packed columns completely failed after only 20 hours of operation. A visual inspection of the equipment's exterior was performed during a site visit. Much of the exterior surface material, constructed of galvanized steel or cast iron, has corroded significantly in the four years of operation. The second design flaw was that the original heat exchanger specified had insufficient cooling capacity during hot weather operations. When the compressed gas was not adequately cooled, moisture removal was reduced which caused the molecular sieves to be less effective. The refrigeration system, with a rated cooling capacity of 35 tons, was replaced with a new unit with a cooling capacity of 100

tons. The new unit was being operated at 50 to 60 tons of refrigeration.

This process cannot be a long term solution to the NO_x problem at this, or any other facility. Union Carbide^x was the sole supplier of the molecular sieves for this process. As a result of Union Carbide's halt in production of these molecular sieves, an alternative process must be implemented. Hercules was investigating if the molecular sieve system could be replaced with another treatment process that is more reliable and less costly to operate and maintain. Hercules has considered replacing the molecular sieve system with extended contact absorption towers.

7.4.2 Molecular Sieves at Holston Army Ammunition Plant Case No. 25

Holston Army Ammunition Plant is a government-owned, contractor-operated (GOCO) facility operated by Holston Defense Corporation, a subsidiary of Eastman Kodak.

Nitrogen oxides (NO_x) are generated as part of the manufacturing process at Holston in the ammonia oxidation process (AOP). In the mid 1970's an Armament Research and Development Command (ARRADCOM) program was conducted to evaluate pollution control devices. One such project involved the evaluation of a molecular sieve system for the reduction of NO_x from AOP tail gas. The PuraSiv-N Process, a proprietary molecular sieve system manufactured by Union Carbide, was selected for study.

The Union Carbide process, designed to reduce NO_x concentration in the nitric acid plant tail gases to less than 50 ppm, involved catalytic oxidation of nitric oxide to nitrogen dioxide followed by selective adsorption of nitrogen dioxide on molecular sieves. Two towers packed in a compound bed arrangement with dessicant and molecular sieves were used to scrub tail gas from the nitric acid absorption column. Wet gas from the nitric acid absorption column was first dried by a dessicant in the first packed section of the NO_x adsorption tower. Dried gas then passed through a catalyst/molecular sieve bed where nitric oxide is oxidized and the resulting nitrogen dioxide is adsorbed. The gas stream from the active NO_x adsorption tower was split into two streams. Normally, the gas was returned to the nitric acid plant for energy recovery. Periodically, as required, the gas was heated and used to regenerate molecular sieves and dessicant in the second adsorption tower. The regenerant gas laden with nitrogen dioxide was returned to the nitric acid absorption column.

Performance tests were conducted intermittently between August 1974 and early 1978. The results of the performance tests indicated that the molecular sieve process technology was successful in reducing the NO_x concentration to less than 50 ppm at an operating cost of approximately \$1 per ton of nitric acid produced (1978 dollars).

While the technology was effective, the operational life of the molecular sieves was limited. The molecular sieves rapidly degraded, causing both unacceptable NO_x emissions and a high pressure drop across the beds. This degradation necessitated their replacement after 258 days of intermittent operation, while their effectiveness had been guaranteed for 2 years by Union Carbide. Changes in the equipment were recommended by Union Carbide in an attempt to reduce degradation of the molecular sieves and extend their useful life. The system was shut down due to a lack of funding before sufficient operating time was accumulated to demonstrate reliability after Union Carbide's suggested changes were implemented.

Much of the original equipment was constructed of materials which did not hold up in the harsh, corrosive environment of a nitric acid plant and consequently failed during the relatively short demonstration test. Copper tubing in the refrigeration unit corroded and was replaced with stainless steel. The compressor in the refrigeration system was damaged by rust particles in the system and had to be overhauled. Gas piping from the adsorption towers to the power recovery unit were constructed of carbon steel, which corroded and was eventually replaced with stainless steel pipes. Carbon steel tubes in the regeneration gas cooler corroded and were replaced with stainless steel tubes. Stainless steel tubes in feed and recycle gas chillers were corroded by the brine used as the cooling medium. After two failures, brine was replaced with water.

In addition to corrosion of process equipment, corrosion was a severe problem with analytical equipment used to monitor the system's performance. While all instrumentation used in this test facility would not be required in an operational system, the severity of corrosion indicated the necessity of providing extraordinary protection of instrument circuitry installed in similar plant environments (4).

Because of all of the above mentioned problems, the system could seldom be operated for more than 2 days at a time, and was shut down and dismantled in 1979. The columns are located at Holston and current plans are to scrap them when funds are available. The cooler, heat exchanger, and refrigeration systems were transferred to Radford Army Ammunition Plant for use as spare parts for a similar NO_x control system (see Case No. 13, Section 7.4.1).

As discussed in Case No. 13 (Section 7.4.1), Union Carbide, the sole supplier of molecular sieves used in this process, no longer manufactures them. The result is that this system could not be implemented at other installations, even if the operational and maintenance problems were to be resolved.

7.4.3 Carbon Adsorption at Radford Army Ammunition Plant Case No. 14

Prior to 1974, pink and yellow waters were discharged from the Radford facility directly to a receiving stream without treatment. From 1974 to 1983, treatment of ammunition wastewaters were not required at Radford since the TNT production plant was being renovated. The treatment system, which has been operating for about 18 months, consisted of settling tanks, a feed tank, two parallel diatomaceous earth filters, two parallel carbon adsorption columns, a surge tank, and a soda ash neutralization tank. The two parallel upflow pulsed bed carbon units, approximately 40 feet high and 5 feet in diameter, were designed to remove nitrobenzenes from a mixture of pink and yellow waters. Influent flow rate and the concentration of nitrobenzenes, as measured by the chemical oxygen demand (COD) were 150 gpm and 4050 mg/l respectively. The treatment plant, which was designed to reduce influent COD to 0.1 mg/l, was to meet an effluent COD standard of 0.5 mg/l.

Treatment of pink and yellow waters with activated carbon has generally been a success. The carbon columns could effectively and efficiently remove nitrobenzenes from the ammunition wastewater. Effluent sampling was performed once a week to determine if the regulatory standard of 0.5 mg/l of COD was being met. In 18 months of operation, two effluent samples exceeded the limitation as a result of carbon beds being operated past their breakthrough point. This operational problem was the result of difficulty in predicting when a nitrobenzene wave front would break through a bed, especially with variations of flow and influent concentration.

The only major problem with the treatment system has been disposal of spent carbon. The treatment system has used approximately 45 tons of carbon per year at an estimated purchase cost of \$75,000. This volume of carbon use was too small to economically justify onsite regeneration. Since this spent carbon has been considered to be a hazardous waste, due to its reactivity, manufacturers of activated carbon have been reluctant to transport the material to their regeneration facilities. As a result, open burning has been used to destroy the spent carbon. Hercules has been investigating the possibility of feeding the spent

carbon to an open hearth furnace currently being constructed for red water destruction.

Operation of the existing treatment system for the removal of nitrobodyes from combined pink and yellow waters was expected to continue.

According to James Morris, Pollution Abatement Coordinator of Hercules, pink water loses its color when it is acidified or has a nitrobody concentration of less than 1.0 mg/l. The pink color develops when the concentration is greater than 1.0 mg/l and is clearly visible at a concentration of 5.0 mg/l. During the site visit to Radford, treated wastewater had a distinct pink color.

7.4.4 Internal Water Recycle at Milan Army Ammunition Plant Case No. 15

One rework facility at the Milan Army Ammunition Plant involved washing used shell casings with hot, steam-heated water (109°F to 123°F). Historically, the process was operated using once-through wash water. Wash water, expected to contain RDX, Composition B, and Composition A in varying and unpredictable quantities, was then mixed with other pink water and treated by filtration and carbon adsorption for removal of nitrobodyes. Maximum flow rate from the shell casing washout process was 102,000 gallons per day.

The modification proposed and implemented was to recycle washout water from a collection sump back to casing washout injectors (5). This system consisted of a submersible pump and associated piping and valves. Materials were specified so as to be nonsparking. Steam was injected into the recycle line.

Recycle of washout water was continued until the wash was no longer effective. Water was then discharged from a sump to a pink water treatment system. The number of cycles achieved by this system was not given in the engineering report.

The system was first tried as a pilot program. Although the system was installed for nearly 11 months, production problems unassociated with the recycle system resulted in the system being used about 2 months. Initially, several PVC piping joints were severely damaged due to direct steam injection into the line. After repair, the system functioned satisfactorily for the duration of the pilot trial period. The only modification recommended by the authors of the report was to fit the system with a flanged "Y" that could accommodate a pig-type cleaner to remove pink solids that accumulate on the interior of the recirculation pipe.

Operation of a permanent system, installed at the conclusion of the pilot trials, was expected to continue.

7.5 References

- (1) Canadian Industries Limited. Newport Army Ammunition TNT Department Manual, September 1970.
- (2) Heck, Robert P. "Adsorption Technology Applied to Wastewaters of the Munitions Industry," presented at the 22nd Annual Technical Meeting of the Institute of Environmental Sciences, Philadelphia, PA, April 1976.
- (3) Rowe, Donald L. et al., Engineering Evaluation of Carbon Adsorption Systems for Pollution Control of Ordinance-Contaminated Wastewater at NWS/Yorktown, Naval Surface Weapons Center, Dahlgren, VA, December 1980.
- (4) Smith, M.R. Evaluation of Pilot Molecular Sieve for NOx Abatement on AOP Nitric Acid Unit, Prepared for Commander, ARRADCOM under contract no. DAAA 09-73-C-0079 by Holston Defense Corporation, subsidiary of Eastman Kodak Company, Kingsport, Tennessee, November 1978.
- (5) Roy F. Weston, Inc., Pilot Plant Study for Water Reuse System for the Milan Army Ammunition Plant, Milan, Tennessee - Final Draft Report prepared for Martin-Marietta, Decatur, GA, December 1984.

WDR93/06

Jet Engine Test Cell

. JET ENGINE TEST CELL

.1 Process Description

Ideally, military jet engines should have an invisible exhaust plume to minimize detection. However, jet engines do produce a visible exhaust, especially when operated at full power.

The visible emission from jet engines, generically termed "smoke," is a complex mixture of aerosols. A large portion is unburned carbon of sub-micron size, which is black, nonreflective, nonpolar, and relatively stable chemically and physically. Another component is aerosol hydrocarbons, a complex mixture of unburned, partially oxidized, and reformed hydrocarbons, with varying chemical, physical and optical properties. The final component is ash, resulting from noncombustible impurities in the fuel, a minor component for jet engines operated on uncontaminated fuels.

Air pollution regulations are being considered to control emissions from civilian aircraft. Military aircraft would be exempt from these regulations. However, when engines are removed from military aircraft for repair and operated in test cells, they lose their military exemption and are subject to local regulation as stationary sources of air pollution.

3.2 Magnitude of Problem

Jet engines, when operated at full power in a test cell, can emit sufficient smoke to violate plume opacity regulations of local air pollution control agencies. The result is that DOD facilities have been issued notices of violation of air pollution regulations at several facilities.

3.3 Proposed Modifications

Four methods have been proposed, and used, to reduce visible emissions from jet engine test cells:

1. Changes in engine design and modifications to effect smokeless combustion.
2. Use of fuel additives, such as ferrocene, which reduce visible emissions by changing combustion or postcombustion reactions.
3. Installation of control equipment to remove or modify the visible smoke.

4. Diluting the exhaust plume with ambient air, usually under the premise that the dilution air is used to cool the hot exhaust gasses.

1 Case Studies

1.1 Conversion From Wet to Dry System at Alameda and North Island NARF's Case No. 21

The current jet engine test cells at Alameda NARF utilize water injected from a ring located at the base of the exhaust stack. Metal obstructions in the stack cause a turbulent gas flow which produces a scrubbing action to reduce smoke emissions. Local air pollution regulations are based on the opacity of visible smoke emissions. Localized fallout of smoke results in dirty laundry and other dustfall problems. During hot weather, plume separation has resulted in the emission of visible smoke.

The new dry test cell uses a significantly greater flow of augmentation air and fuel additives to reduce the opacity of the emitted smoke. Fuel additives used are Cerium Hexchem for TF-41 engines and ferrocene for J-57 engines. The dry cell also produces significantly less noise than the old test cells.

Existing jet engine test cells at NARF North Island, located in San Diego, California, were originally constructed during World War II. These cells had been extensively modified over the years and were in poor condition. Water injection had resulted in severe concrete and steel corrosion problems.

In the old cells, water injection seemed to reduce opacity by a scrubbing action. The water injection was used only during testing of engines when afterburners were being used. During low speed testing, smoke seemed to build up in the stack and then to be exhausted in puffs of smoke that exceeded the opacity limit. Experiments were performed in which water was injected continuously during all phases of engine testing. This seemed to reduce the smoke emission. This testing was discontinued, because the test cell that was being used became inoperable due to corrosion failure.

The air augmentation test cells were selected to replace existing cells when needed. The primary reason for using air augmentation is to reduce noise. As a side benefit, the opacity of the exhaust plume was significantly reduced.

With the new air augmentation test cells, smoke opacity has been reduced by two effects. Air augmentation results in a

tion of the exhaust, resulting in a proportional action in opacity. Also, increased turbulence in the must was claimed to result in increased dispersion of cycles. The steadier exhaust flow has eliminated the "fing" effect noted in the wet test cells at low engine speeds.

far, the new test cell has been successful at reducing visible air emissions, although the workload on "dirty" lines has been reduced and therefore the test cell has not been extensively tested. A second air augmented test cell is under construction, and it is anticipated that any new cells built to replace the existing aging units will be of similar design.

93/06

AD-A157 319

INDUSTRIAL PROCESSES TO REDUCE GENERATION OF HAZARDOUS 2/2
WASTE AT DOD FACIL. (U) CH2M HILL INC GAINESVILLE FL
T E HIGGINS 15 FEB 85 WDR-93/02 DACA87-84-C-0076

UNCLASSIFIED

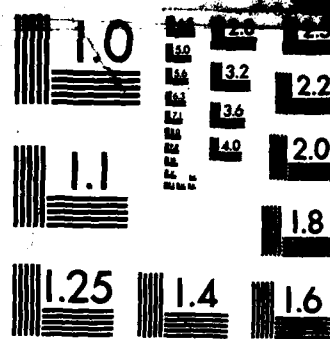
F/G 13/2

NL

END

FILED

DEC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Fire Fighting Training

9. FIRE FIGHTING TRAINING

9.1 Process Description

Fire fighting training is performed at seven Naval Air Stations. In the past, aqueous film-forming foam, more commonly known as AFFF (military specification IL-F-24385C), was used in Naval Fire Fighting Schools to put out fuel oil fires. AFFF, an excellent surfactant, has also been used to extinguish shipboard fires during both training exercises and during actual emergencies. AFFF, manufactured by the 3M Company and the Ansul Company, is a mixture of water, butyl carbitol, urea, synthetic detergents, and fluoroalkyl surfactants. It is sold as a liquid in three concentrations, which when used are diluted to a 6 percent, 3 percent, or one percent concentration (1).

Fire fighting training has been conducted by setting diesel marine fuel oil on fire in open earthen pits and then extinguishing the flames with a 6 percent solution of AFFF. After the training exercises were finished, the waste oils laced with AFFF had to be removed from the pit for disposal. It has been difficult to contract commercial firms for the disposal of the contaminated oil because: (1) the material cannot be easily treated by gravity or dissolved air flotation oil water separators due to the emulsifying properties of the foam, and (2) the material is not readily biologically degraded by unacclimated microorganisms. AFFF is also undesirable due to relatively high cost, potential toxicity of products release from thermal reactions, and possible toxicity to aquatic life.

9.2 Magnitude of Problem

AFFF is used at Navy Ship Yards, Naval Air Stations, Air Force bases, and various Army facilities. AFFF wastewaters are not considered to be hazardous; however, it has become costly and troublesome for the armed services to dispose or treat this waste material.

9.3 Proposed Modifications

In response to these problems, the Navy performed a study to determine if a surrogate could be found to replace AFFF (2). Sixteen commercial surfactants were studied in detail as candidate substitutes based on their potential for meeting the following criteria:

- o Readily available in large quantities
- o Nonflammable

- o Environmentally acceptable
 - Disposable in effluent
 - Biodegradable
- o No adverse effects on human health and safety
- o Adequate foaming action
- o Stability at high temperatures
- o Minimally corrosive
- o Cost-effective for training

This study recommended that Ultrawet K, a linear alkyl-benzene sulfonate manufactured by ARCO, Inc., be used in lieu of AFFF for fire fighting training. Ultrawet K does not exhibit the same emulsifying properties as AFFF and is also more amenable to biological treatment. Ultrawet K is relatively nontoxic to humans, is nonflammable, and produces a high quantity of foam that does not dissipate at high temperatures. This study also recommended that use of open earthen pits be replaced with computerized control "pollution free" facilities. The Navy thus issued a directive ordering the seven fire fighting schools to switch to Ultrawet K and to replace the earthen pits with modern enclosed facilities. All schools now use Ultrawet K for fire fighting. However, according to Naval Facilities Engineering Command, AFFF continues to be used on board ships and in some open pit fire drills. Computerized facilities are being designed, constructed or are already in operation at the seven Navy facilities.

The Air Force has evaluated the treatability of AFFF. They found that acclimated microorganisms easily biodegrade low concentrations of AFFF. Since a 6-percent solution of AFFF has a biochemical oxygen demand of 300,000 mg/l and a chemical oxygen demand of 400,000 mg/l, AFFF-laden wastewater must be slowly fed to a treatment facility. 3M Corporation recommends that one gallon of 6-percent AFFF should be diluted with 10,000 gallons of sewage to prevent serious foaming in aeration basins and to prevent sludge settling problems in clarifiers. The Air Force has determined that AFFF can be effectively treated with land farms, trickling filters or activated sludge plants. Air Force research has found that if the AFFF concentration in wastewater exceeds 250 mg/l, the surfactant causes poor settling in clarifiers. AFFF concentrations must therefore be kept low to ensure efficient biodegradation and settling. The Air Force has switched from a 6-percent AFFF solution to a more dilute 3-percent solution. This modification results in increased wastewater flow but this increased quantity is more easily treated.

9.4 Case Study

9.4.1 Replacement of AFFF with Ultrawet K at Norfolk Naval Air Station Case No. 35

At Norfolk Naval Air Station, Ultrawet K has totally replaced AFFF at the Fire Fighting School. Training is performed 5 days a week, 49 weeks per year. Approximately 1,200 gallons of Ultrawet K is used per year during training. Oily wastewaters are being treated by a small dissolved air flotation unit that separates oil from water and removes solids. The pretreated wastewater is discharged to a public sewer for secondary treatment at a publicly owned treatment plant.

The computerized facilities at Norfolk are fully operational. Some problems have been encountered with mechanical and computer failures. When these occur, the school reverts back to open pit training.

AFFF is continuing to be used on board ships in lieu of Ultrawet K because it is a better extinguisher. At Norfolk, AFFF wastewaters from ships are being disposed of by Norfolk Public Works Center's (PWC) hazardous waste disposal division. The PWC has a permit to slowly bleed the AFFF wastewater to a public sanitary sewer. PWC will shortly be receiving an oil water separator for pretreatment of the AFFF wastewater.

9.5 References

- (1) Booz, Allen & Hamilton, Inc. Fire Fighter Trainer Environmental Considerations, Phase I, prepared for Advanced Technology Systems & Naval Training Equipment Center, January 8, 1981.
- (2) Booz, Allen & Hamilton, Inc. Fire Fighter Trainer Environmental Considerations, Phase II, prepared for Advanced Technology Systems & Naval Training Equipment Center, July 1, 1981.

WDR93/06

Fuel Tank Cleaning

10. FUEL TANK CLEANING

10.1 Process Description

Army, Navy, and Air Force facilities store various types of fuels in steel tanks. These fuels generally fall under three categories: aviation fuels, ground and marine fuels, and burner fuels. Aviation fuels include turbine fuels (grades JP-4 and JP-5, military specification MIL-T-5264) that are primarily used by jet cargo, bomber, and fighter aircraft; and aviation gasoline (grades 80/87, 100/130 and 115/145, military specification MIL-G-5572) which is used in smaller propeller driven utility aircraft. Ground and marine transportation fuels include leaded, unleaded, and premium automotive gasoline (federal specifications VV-G-76 and VV-G-001690) that is used in most non-combat motor vehicles; type I and II automotive gasoline (military specification MIL-G-3056) that is used in combat vehicles; diesel fuel oil (grades DFA, DF-1 and DF-2, federal specification VV-F-800) which is used in motor vehicles; and diesel marine fuel oil (military specification MIL-F-16884) used in ships. Burner fuel oils include those that meet military specification MIL-F-859 and grades 1-6 fuel oils which meet federal specification VV-G-815.

Department of Defense has published a military standard (MIL-STD-457A) for the inspection and cleaning frequency of petroleum fuel operating and storage tanks (1). Operating or day tanks are defined as fixed tanks from which fuel is dispensed to military equipment on a regular basis. Bulk storage tanks are fixed tanks utilized to receive, store and issue fuel other than directly to military equipment. Military standards establish schedules for the inspection of tanks containing aviation, ground, marine, and burner fuels.

DOD standards allow aviation fuel tank facilities two options in determining the frequency of fuel tank inspection and cleaning. A facility may choose to inspect tanks on a fixed schedule (Option A); or a facility may determine the need for detailed internal inspection and possible cleaning based on product sampling, testing and data analysis (Option B).

Option A requires visual inspections of aviation fuel tanks at one, two or three year intervals depending upon whether or not incoming fuel is filtered or if the tanks are lined. Visual inspection is defined as inspection of the interior from a manway opening or any other means without physical entry into the tank. Under Option A, aviation field tanks must undergo a physical entry inspection every 3, 4, 5, or 6 years depending upon whether the incoming fuel is filtered or if the tank is lined. All product must first be removed

and safety standards met before inspection personnel are allowed to enter a tank.

Physical entry inspection is also required when visual inspection reveals deteriorating conditions which could effect product quality or result in future excessive maintenance costs if uncorrected. Tank cleaning is performed when physical entry inspection indicates that product quality is being adversely effected.

Option B requires that operating tanks be sampled monthly to determined if interior inspection or cleaning is required. A representative or composite sample of the product must be taken downstream from the tank discharge and prior to filtration action. Samples are to be taken monthly from active bulk storage tanks, every four months from inactive storage tanks, and after tanks are replenished with new product. DOD regulations do not stipulate frequency of sampling tank bottoms. Individual services determine the frequency of sludge sampling and analysis.

Interior inspection of an aviation fuel tank is required if the particulate concentration of a sample approaches or exceeds the deterioration limit established for that specific product by the DOD. Product quality can deteriorate rapidly or slowly over a number of years. Tanks are required to be internally inspected when analysis of tank bottoms indicate that the material is hazardous, or if excessive anaerobic microbial growth is occurring, or when the sludge blanket depth become excessive. The extent of tank cleaning is based on observations made during interior inspection.

The minimum sampling frequency of ground, marine, and boiler fuels in operating and bulk storage tanks is specified in "Quality Surveillance Handbook for Fuels, Lubricants and Related Products" (MIL-HDBK-200) (2). Active operating tanks are generally required to be visually inspected daily and active bulk storage tanks visually inspected weekly. Samples of dormant product are analyzed yearly or whenever suspected of being "off-specification." Samples are analyzed to detect undesirable product characteristics which will indicate unsatisfactory interior tank conditions such as excessive interior rusting or liner deterioration, buildup of sludge, or anaerobic microbial growth. A physical entry inspection is required whenever sample quality goes below deterioration limits published in MIL-HDBK-200.

Petroleum fuel tank cleaning is performed by contractors. Cost reductions are realized by cleaning several tanks under one contract. Usable product is first removed from the tank by the government, leaving approximately one-half to 2 feet

of waste fuel and sludge. The contractor is responsible for pumping remaining fuel into 55-gallon drums, analyzing it to determine if it is a hazardous waste; and if hazardous, disposing of the material in accordance with RCRA regulations. If it is determined not be hazardous, the contractor is normally required to turn the waste fuel back to the government for reclamation and reuse.

Tanks are cleaned with a general purpose pine oil detergent (Federal Specification O-D-1276B), a volatile cleaning solvent (Federal Specification TT-T-291F), or with an approved commercial cleaning agent. Sludge is pushed to a central hopper using a power hose, brooms and squeegees. Sludge and wash water are pumped from the hopper to a tank truck and transported to an EPA-approved disposal area. Tank bottoms are usually treated and disposed of at a sludge farm. If sludge is from tanks containing leaded fuels, the material is usually classified as hazardous and disposed by the contractor in accordance with RCRA regulations. The contractor is required to remove scale and other adhering materials by sand blasting or power wire brushing.

10.2 Magnitude of Problem

Thousands of aviation fuel, ground and marine fuel, and boiler fuel tanks are located at Army, Navy, and Air Force installations in the United States. Cleaning produces sludge and wash water wastes. Laboratory tests on sludges have shown that these materials are usually not hazardous. However, sludge from tanks containing leaded gasoline are usually disposed of as a hazardous waste. Special fuel additives can also sometimes cause the sludge to be considered hazardous. Since tanks are cleaned infrequently and the wastes produced are only infrequently classified as hazardous, the amount of hazardous sludge produced at United States military installations by fuel tank cleaning is not significant.

10.3 Proposed Modifications

It has been suggested that the quantity of hazardous waste produced at fuel storage facilities can be reduced by increasing the frequency of cleaning. Some believe that, in reality, fuel tanks are cleaned only when a massive buildup of sludge results in intolerable operating conditions. It was reasoned that if tanks were cleaned more frequently, tank bottoms would be less likely to be contaminated with hazardous materials.

Military regulations specify that fuel tanks should only be cleaned when inspections or chemical testing indicates that a sufficient buildup of sludge, toxic chemicals, heavy metals, hydrogen sulfide, or rust may cause degradation of

product quality. In contrast to those who recommend more frequent cleaning, some feel that as long as facilities follow current DOD regulations, the production of hazardous waste should be minimized. If tanks are cleaned more frequently than currently specified, the quantity of wastes would likely increase due to the larger volumes of wash water that would be generated. Current DOD regulations appear to be adequate.

10.4 Case Studies

10.4.1 Craney Island and Yorktown Fuel Farms Case No. 38

Craney Island Fuel Farm located in Portsmouth, Virginia operates 76 fuel storage tanks, storing diesel marine and light fuel oils (NATO 7 F76). Fuel tanks are cleaned when visual inspection and sampling reveal an undesirable sludge buildup or sulfide generation. Currently, twenty tanks are being cleaned by a contractor.

All fuel is first removed from the tanks. Fuel not meeting specification is sent to an oil recovery facility located onsite. The contractor is responsible for disposal of waste oils that cannot be reclaimed. Approximately one-half to one foot of sludge must be removed from the tanks by the contractor. Samples of sludge are sent to an EPA certified laboratory where they are analyzed for flammability, total lead, and EP toxicity. Sludge that is classified as hazardous is disposed of by the contractor at government's expense following RCRA regulations. In 1983, two tanks that were cleaned at Craney Island were found to contain hazardous sludge. Sludge from one tank, which in the past had been used to store leaded gasoline, had a high lead content and consequently failed the Extraction Procedure (EP) toxicity test. The other tank was previously used as a general slop tank and contained paint thinners and other materials which are listed by RCRA regulations as being hazardous wastes. It cost \$45,000 (\$2-\$3 per gallon) to remove and safely dispose of these hazardous materials. None of the twenty tanks currently being cleaned at Craney Island have been found to contain hazardous sludges, largely because leaded gasoline is no longer stored at the site.

It cost \$8,000 to \$10,000 to clean a 2-million gallon fuel tank containing nonhazardous materials.

Tank bottoms classified as nonhazardous are disposed of on two onsite sludge farms covering 15 acres. The sludge and wash water is sprayed on the fields and mixed into the soil with a disk and rototiller. Waste oils are biodegraded by microorganisms and wastewater evaporates. The sludge farms, surrounded on three sides by the Elizabeth River Estuary,

have a zero discharge permit. Waste is applied at low rates during times of favorable climatic conditions to minimize leachate percolation to the groundwater or runoff to the surrounding river. Waste oils have been successfully biodegraded for six years. In 1980, problems developed when a high application rate of tank bottoms caused a dieoff of treatment bacteria. This incident resulted in the opening of the second sludge farm. Until 1980, corn was grown at the sludge farm. This practice was discontinued since it was found that biological activity was greater on bare field.

Yorktown Tank Farm, located in Yorktown, Virginia, contains 26 tanks, 6 of which are used to store gasoline. The remaining 20 tanks contain JP4 aviation fuel and Bunker C oil. Volumes of these tanks range from 1.5 to 2.75 million gallons.

Tanks are cleaned at Yorktown every 3 to 5 years when the sludge reaches a thickness of 6 to 8 inches. Sixteen tanks were cleaned in 1983 at an estimated cost of \$10,000 per tank. According to Yorktown personnel, no laboratory tests were performed on the sludge. All of the sludge and sand blast residue was disposed of offsite in a commercial hazardous waste landfill. In the past, the waste materials were buried onsite.

10.5 References

- (1) Frequency of Inspection and Cleaning of Petroleum Fuel Operating and Storage Tanks, MIL-STD-457A, Department of Defense, November 10, 1980.
- (2) Qualization Handbook for Fuels, Lubricants and Related Products, MIL-HDBK-200F, Department of Defense, September 15, 1980.
- (3) Cleaning Petroleum Storage Tanks, NavFac Specification TS-13657, Department of the Navy, Naval Facilities Engineering Command, December 1978.

WDR93/06

Purchase and Use Specifications

11 PURCHASE AND USE SPECIFICATIONS

11.1 Process Description

Many items purchased by the military are stamped with an expiration date. In most instances, this expiration date is based on expected shelf-life of the material or its container and is typically 2 to 5 years after the product was manufactured. Common materials, such as paints, paint thinners, cleaning solvents, oils, and greases, all have stamped expected lives. When the expiration date passes, the items are removed from storage and turned over to the Defense Property Disposal Office (DPDO) for disposal. Many of these virgin materials then are classified as hazardous wastes because of one or more undesirable characteristics--corrosivity, flammability, reactivity, toxicity, or because their constituents are listed by the EPA as being hazardous.

In May of 1980, DOD delegated responsibility for worldwide disposal of all hazardous materials to the Defense Logistics Agency (DLA), excepting: radioactive materials; chemical warfare materials; ammunition; municipal refuse; contractor generated materials; sludge from municipal or industrial wastewater treatment plants; refuse generated from mining, dredging, construction, or demolition operations; and waste generated from research and development programs. The Defense Property Disposal Office (DPDO), which is a division of DLA, is specifically responsible for storage and disposal of hazardous wastes generated by the three armed services.

DPDO storage facilities are usually located at the same military site in which the waste is generated. The armed services are required to properly identify, package, and label these wastes. There are provisions to extend the expiration dates of materials still nearing military specifications and whose containers are still in good shape. However, rarely are expiration dates extended because it is easier to obtain new material. If the expired shelf-life material cannot be reused, it is disposed of by a contractor according to RCRA regulations. If the material can be reused, it is listed on DLA's excess property listing (EPL) and then goes through the reutilization, transfer, disposal, and sale (DPDS) process. For instance, assume that 100 cases of lead-based paint with an expired shelf-life were stored at a DPDO warehouse at a Naval Shipyard. Other Navy facilities would have first priority in claiming the unwanted material. The other armed services would then have priority in claiming the listed item, followed by other federal agencies. The paint would then be available for donation to local and state governments and nonprofit organizations. If the material is still not claimed, it could then be sold at an auction to members of the general public or private industry. If the paint could not be

implemented as proposed, proved cost-effective, and was sustainable or capable of being carried on indefinitely. Modifications that met these criteria were classified as successful (S). Those process modifications found not to be successful (U) failed for a variety of reasons, which are explained in footnotes (a through m) to Table 13.1. Those modifications for which insufficient information was available, or for which implementation was too early in progress to evaluate, are designated with an N; and the rationale for this designation is also explained in footnotes to Table 13.1.

13.2 Distribution of Recommended Cases

The 18 cases recommended for further evaluation included 13 that were successful and 5 that were not. By service, there were 3 Army, 6 Air Force and 9 Navy cases, approximately proportional to the distribution of the original 40 cases.

By industrial process, 7 of the cases involved modifications to plating operations, 5 were for modifications to painting or paint stripping, 5 were for modifications to recover solvent, and 1 was to modify purchase and use specifications to reduce disposal of items whose shelf life had expired. Selection of these cases fulfills the objective of the contract to "...focus on a few processes that generate the greatest proportion of DOD hazardous wastes..."

There are, in these eighteen cases, numerous candidates for the three "Project of Excellence" to be selected during Phase 2 of the project.

WDR93/06

evaluation. Cases were favored in which the modification was seriously attempted, resulting in the production of reports or other information suitable for further analysis.

Some of the cases involved wastes that would not be classified as hazardous under EPA regulations. Since the purpose of this project is to evaluate process modifications to reduce generation of hazardous wastes, these cases were considered to be less useful than those that dealt with hazardous wastes.

An assessment model was prepared to help evaluate cases for consideration for Phase 2 of the project. This model evaluated cases according to the following five criteria:

Concrete Example: Was there a modification proposed, and is sufficient information available (i.e. existing operation, reports, conversations with personnel) to perform a detailed study of the modification?

Waste Reduction: To what extent would the proposed modification, if successful, effect a significant reduction in waste generation at the facility?

Waste Generation: At the average facility using the industrial process, how much waste is produced that would be affected by the proposed modification?

EPA Hazwaste: Would the affected waste be classified as a hazardous waste under EPA regulations? (For a detailed description of EPA hazardous waste regulations and definitions, see 40 CFR Part 261-- Identification and Listing of Hazardous Waste).

Potential Use: How widely is the process used in the Armed Services? Would the process modification have widespread application?

Notice that the five criterion do not judge the success (or lack thereof) of a given modification.

The evaluation of whether or not a process modification was successful was separated from the determination of its value as an example for further analysis.

To determine if a modification was successfully applied, we evaluated whether or not the modification had been

13. RECOMMENDATIONS

The prime objective of Phase 1 of this project and consequently this report is to recommend eighteen cases for further evaluation in Phase 2.

The forty cases outlined in Chapters 3 through 11 of this report were evaluated for inclusion in Phase 2 of the project. This evaluation was based on each case's usefulness as examples of how processes can be implemented rather than on how successfully each modification was applied in the given case.

13.1 Evaluation and Recommendation of Cases

Table 13.1 shows the assessment of each case, and indicates the 18 cases recommended for further study in Phase 2. Cases were favored in which modifications were seriously attempted, had a widespread application, and had the potential of effecting a significant reduction in hazardous waste generation. Cases recommended for further study in Phase 2 of the project are designated with a star (*).

In all but two cases, the cases earning the highest score under our assessment model were recommended for further study. The two cases earning high scores, but not recommended for further study (Case No. 24, Solvent Recovery at Kelly AFB, and Case No. 22, Dry Media Paint Stripping, Alameda NARF), both failed to offer sufficient information to warrant further evaluation.

The selection criteria was based on several objectives. In the contract document, the Architect/Engineer (CH2M HILL) is directed to:

"... focus on a few processes which generate the greatest portion of DOD hazardous wastes, such as electroplating or paint stripping, under the premise that an in-depth study of these with an implementable action objective is more in line with the overall goal of environmental improvement than a cursory cataloging of a large number of DOD industrial processes for potential action only ..."

Therefore, the selection criteria selected were those that favored process modifications that could have reduced large quantities of wastes at the facility investigated, and that were widely applicable to other DOD facilities.

Some process modifications were not implemented for immediately and obvious and overwhelming reasons, such as lack of money or manpower. For these cases, little additional useful information would be obtainable for further

Recommendations

12.2.8 Fuel Tank Cleaning

The cleaning of fuel tanks at military facilities sometimes has created hazardous waste. Based on a study of the Navy's Craney Island and Yorktown fuel farms (Case No. 38), it was determined that current DOD inspection and cleaning schedules ensures that waste production is minimized.

12.2.9 Purchase and Use Specifications

Many virgin materials at military facilities have been classified as hazardous wastes because of expired shelf-life. Many Navy personnel have recommended relaxing overly restrictive purchase and use specifications for shelf-life items to reduce the quantities of hazardous waste generated. In 1983, approximately half of the hazardous waste generated at the Navy's Norfolk facility (Case No. 40) was expired shelf-life material. No DOD policy changes have yet been implemented to correct this disposal problem.

WDR93/06

degreasers. A flushing rig at Charleston NSY (Case No. 36) has been used to clean Freon refrigerants for reuse in shipboard refrigeration units. The purchase of a similar flushing rig was cancelled by Norfolk NSY (Case No. 37) due to manpower limitations. Anniston Army Depot (Case No. 39) has successfully recovered trichloroethylene with individual distillation units that are attached to vapor degreasing tanks. Pensacola NARF (Case No. 30) failed to economically recycle machine tool coolant due to inadequate material purchasing policies.

12.2.5 Explosives Manufacturing

The manufacture of conventional explosives, such as TNT and propellants, create unwanted air pollutants and hazardous wastewaters. Nitrogen oxides are created as a byproduct of propellant production. While they are not considered hazardous substances, they are an EPA criteria air pollutant. Red, yellow, and pink waters are EPA hazardous wastes generated in the manufacture of TNT. A molecular sieve gas adsorption system installed at Radford Army Ammunition Plant (Case No. 13) reduced the atmospheric emissions of nitrogen oxides to meet air pollution standards. However, the system has frequently been inoperable due to mechanical failures and has been extremely expensive to operate and maintain. A similar molecular sieve system at Holston Army Ammunition Plant (Case No. 25) was taken out of operation of 1978 due to constant mechanical difficulties. Pink and yellow waters at Radford (Case No. 14) are being effectively treated by carbon adsorption. Milan Army Ammunition Plant (Case No. 15) successfully reduced wastewater flows by recycling water generated in the washing of shell casings.

12.2.6 Jet Engine Test Cell

During the testing of jet engines, the emission of exhaust smoke often violates state or local air pollution standards. Conventional test cells use a "wet" scrubbing action to reduce smoke emissions. They frequently do not work properly during hot weather and produce wastewater that must be treated. Alameda and North Island NARFs (Case No. 21) have successfully converted to a dry test cell which abates visible emissions by addition of a fuel additive and dilution of the exhaust plume with ambient air.

12.2.7 Fire Fighting Training

Naval fire fighting schools have used aqueous film forming foam (AFFF) to extinguish fuel oil fires. Although not hazardous, AFFF wastes are difficult and expensive to dispose of. Norfolk NAS (Case No. 35) switched to an extinguishing called Ultrawet K which has proved easier and less expensive to treat.

Plant (Case No. 16) treats metal and cyanide wastes with an innovative treatment plant which employs cyanide destruction, chromium reduction, and metal sulfide precipitation. Anniston Army Depot's plating shop (Case No. 18) has reduced hazardous waste production by carefully operating and maintaining plating baths so that the need for bath dumps is nearly eliminated. Safety was improved at Alameda NARF (Case No. 19) by separating process tanks containing acidic solutions from alkaline cyanide tanks. Alameda NARF (Case No. 20) failed to install conductivity rinse controls and countercurrent rinse tanks due to perceived operational problems and space limitations, respectively. Watervliet Army Arsenal (Case No. 23) has reduced waste by recovering metals from rinse waters for plating bath makeup. The plating shop at Mare Island NSY (Case No. 31) reduced wastewater flows from 81,000 gpd to 60,000 gpd by manually controlling rinsewater flows, and by maintaining proper plating bath chemistry to decrease the frequency of bath dumps. No information could be obtained on reducing drag-out at NARF plating shops by placing a water layer on top of methylene chloride tanks (Case No. 32). North Island NARF (Case No. 33) has greatly reduced cadmium and cyanide wastes by utilizing Ion Vapor Deposition of aluminum in lieu of conventional cadmium plating. Pensacola NARF, which presently plates steel parts with cadmium using vacuum deposition, would like to reduce waste by switching to Ion Vapor Deposition of aluminum. They have been unable to do so because of budget cuts and conflicting military specifications.

12.2.4 Recycle of Solvents and Other Organic Fluids

Solvents and other organic fluids are used at virtually every military facility. They are used for cleaning, degreasing, paint booth cleaning, instrument calibration, refrigeration, and machining operations. Some solvents and organic liquids can be recovered by batch distillation and recycled. Other fluids can be recycled by unique, innovative treatment and recovery processes. Warner Robins AFB (Case No. 4) has successfully recycled solvents with a still, recovered heat transfer fluid by liquid-liquid separation, and separated purging fluid from JP-4 fuel by solar distillation. Tyndall AFB (Case No. 5) failed to economically recycle Stoddard solvent (PD-680) with a vacuum still due to lack of waste solvent. Norfolk NARF (Case No. 7) was unable to meet military specifications with heptane recovered with a batch still. However, Norfolk NSY (Case No. 8) was able to redistill waste solvents used in cleaning operations at the paint shop. A contractor is evaluating if calibration fluid can be redistilled at Kelly AFB (Case No. 29). Pensacola NARF (Case No. 29) has operated small stills for the recovery of Freons on occasion, and has stopped recovering solvents used in vapor

12.2.2 Painting

At most military facilities, conventional solvent spray painting is used to coat the surfaces of parts, vehicles, and structures. When solvent based paints are used, volatile organics compounds are emitted to the atmosphere and large quantities of hazardous waste by-products are produced. Alternatives to conventional solvent based spray painting to reduce or eliminate solvent usage include: dry powder coatings, wet electrostatic painting, electrocoat-ings, high solids coatings, waterborne coatings, and improved painting techniques. All of these modifications have been tried at military facilities with varying degrees of success. Hughes Aircraft (Case No. 2) has successfully used powder coating for the interior of Phoenix missile fuselages, but unsuccessfully used electrostatic painting for TOW missiles. Personnel at Lockheed (Case No. 3) have investigated robotics, water based primers, high solids coatings, and powder coating. They found that use of conventional solvent based spray painting resulted in a better product than that produced by these alternate painting methods. Lockheed has been successful with a modern conveyance system which improves product, reduces cost, and slightly reduces waste.

The NARF's at Pensacola and Jacksonville (Case Nos. 27, 34) obtained promising results when they replaced solvent based chromate primers with water based primers. However, attempts to use electrostatic powder painting and various new spray guns failed at Pensacola. Alameda NARF successfully used airless spray guns to apply paint on large aircraft and plan to switch to water based primers.

12.2.3 Metal Plating

Metal plating is performed in some capacity at almost all military facilities. Hazardous metal and cyanide wastes from electroplating shops must be properly treated and disposed of. Several process modifications have been suggested to reduce generation of hazardous metal plating wastes. Lockheed's plating shop (Case No. 6) successfully switched from a cyanide to a non-cyanide cadmium bath. Pensacola NARF (Case No. 9) and Charleston NSY (Case No. 12) were unsuccessful in recovering chromium from rinsewater due to inappropriate use of technology. However, Pensacola NARF (Case No. 10) has eliminated rinsewater waste by installing a recirculating spray rinse system, and has reduced the need for plating bath dumps by installing a treatment system to remove impurities. Some proposed process modifications, such as a steam condensate recovery system that will be installed at Pensacola NARF (Case No. 11) to reduce deionized water makeup in the plating shop, does not involve the reduction of hazardous waste. Tobyhanna Army Ammunition

production functions to environmental protection. Allocation of manpower slots for environmental protection was particularly difficult to obtain.

4. Successful modifications were usually straightforward and simple to operate, thus requiring minimal training for personnel unfamiliar with the technology involved.
5. Process reliability had to be high so as not to adversely affect production.
6. At facilities where modifications were successful, true costs of hazardous waste disposal were appreciated by management, and were considered in the decision to implement the modifications. At DOD facilities, the Defense Property Disposal Office (DPDO) takes hazardous waste without charge. This has resulted in a disincentive to production people to reduce their generation of hazardous wastes since costs of waste disposal are not charged to production activities. At some facilities, industrial treatment facilities have been sized to handle the existing waste flow. This has resulted in a disincentive to reduce waste production.

12.2 Evaluation Results

12.2.1 Paint Stripping

Conventional wet paint stripping at DOD facilities results in the production of significant quantities of hazardous waste. Several industrial modifications have been proposed to reduce the quantities of methylene chloride, phenolic, and caustic wastes produced by these stripping operations. The most promising modification accomplishes paint removal by blasting with a dry plastic media. Advantages of this stripping technique are that solvent use is eliminated and hazardous waste disposal is greatly reduced. However, dry paint stripping will not completely replace wet stripping due to the following disadvantages: aircraft containing thin skins are not readily amenable to dry blasting, dry paint stripping requires skilled operators, and OSHA has expressed a concern that generation of dust may pose a possible explosion hazard. Hill Air Force Base (Case No. 1) and Pensacola NARF (Case No. 26) have successfully used plastic media to strip whole aircraft and their component parts. Alameda NARF (Case No. 22) and Anniston Army Depot (Case No. 17) rely on conventional wet paint stripping techniques.

12. CONCLUSIONS

During Phase 1 of the project, forty cases were evaluated dealing with a few industrial processes which generate the greatest portion of DOD hazardous waste, including paint stripping and painting, electroplating, and solvent cleaning. These three processes are represented by thirty-two of the forty cases investigated. In addition, cases involving explosives manufacture, jet engine test cells, fire fighting training, fuel tank cleaning, and purchase and use specifications were examined. Case studies from the three armed services were evaluated on the basis of costs, energy consumption, technical practicality, management, incentives, and program monitoring and auditing.

12.1 Features of Successful Modifications

Industrial modifications were generally found to be successful; however, some modifications failed and others could not be adequately evaluated. The criteria and scoring system used in evaluating the modification are explained in Section 13 ("Recommendations"). That section also lists the 18 modifications recommended for further evaluation in Phase 2 of the project.

In general, a number of common features distinguished successful process modifications from those that were not. These features are outlined below:

1. Production people were enthusiastically and actively involved in implementing successful process modifications. This usually required that some incentive be offered by the modification, such as reduced manpower requirements or simplification of the process. The change could not harm product quality, and preferably was an improvement over existing processes.
2. A "champion", who strongly believed in the modification, ramrodded the project and overcame developmental problems and the inertia that protects existing processes (especially those that function, although they may produce undesirable wastes).
3. Support was provided at a sufficiently high level in the chain of command to affect production and environmental policy decisions. Frequently, waste disposal and environmental protection were viewed as service functions, subservient to the mission of the facility, which was usually production-oriented. Successful modifications usually required the reallocation of resources from

Conclusions

246,000 gallons of the material was reutilized, transferred, or sold by the DPDO. The remaining 231,000 gallons was turned over to a contractor for recycling, resale and reuse or was disposed of in accordance with RCRA regulations.

In April of 1981, the Atlantic Division--Naval Facilities Engineering Command, conducted a survey to determine the impact of expired shelf-life items on the Hazardous Waste Disposal Facility administered by Norfolk PWC. Approximately 27,100 gallons of hazardous waste were accepted in April, 1981. It was estimated that 13 percent of this material (3,600 gallons) was expired shelf-life material. The total cost of initial purchase and disposal of this expired shelf-life material was approximately \$38,000. This cost estimate did not reflect intermediate handling costs or administrative costs. Extrapolation of this monthly figure would result in a yearly cost of \$456,000. If intermediate handling costs and administrative costs were considered, disposal of expired shelf-life material at Norfolk would cost well over a half million dollars a year. The total volume of expired shelf-life material handled at Norfolk has increased dramatically since 1981. It is estimated that the current yearly cost of disposing of expired shelf-life items at Norfolk exceeds one million dollars.

It should be pointed out that the quantity of expired shelf-life items experienced at Norfolk is not typical for naval facilities. Norfolk and Pearl Harbor generate the most expired shelf-life waste because these large facilities handle much more ship traffic than other facilities.

Personnel at Norfolk have repeatedly asked that the Naval Supply System Command modify purchasing procedures for new shelf-life material, extend the expiration dates of many current shelf-life items, and repackage defective containerized items. The problems at Norfolk have been well documented during the last three years; however, no substantial corrective measures have been implemented to rectify the situation.

11.5 References

- (1) Dempsey, J.G., "Management of Expired Shelf-Life Material," Memo for Commander, Atlantic Division, Naval Facilities Engineering Command, 114:SGO 6280, October 13, 1981.

WDR93/06

container is in good shape, the item will still usually be disposed of after expiration of the shelf-life date. It has been suggested that these items should have their shelf-life extended. Some containers are dented, exhibit surface corrosion, or show indications of leakage. It has been recommended that these materials be repackaged at Naval Supply Centers, or that purchase contracts be revised so that suppliers are responsible for replacement or repackaging of defective containers.

In October of 1981, the Atlantic Division--Naval Facilities Engineering Command recommended the following (1):

- (1) Items that are transferred to the DPDO should be marked either as an expired shelf-life item or as a valid hazardous waste. This would enable the Navy to monitor disposal of expired shelf-life items by ships and activities.
- (2) An extensive study of the shelf-life problem should be performed to review procurement specifications, validate shelf-life expiration dates, and, where feasible, eliminate shelf-life requirements on stable compounds. These steps would help reduce overstocking of specific items.
- (3) All Navy disposal operations should report the quantities and cost of disposing of expired shelf-life items on a quarterly or semiannual basis to Naval activities, commands, and ships. Supply and Material Departments at affected activities should review these reports to help eliminate over procurement of shelf-life items.

To date, none of these recommendations have been successfully implemented.

11.4 Case Studies

11.4.1 NSY and NARF, Norfolk, Virginia Case No. 40

The DPDO at Norfolk, Virginia handles large quantities of hazardous waste generated by the Naval Ship Yard and Naval Air Rework Facility. Since January of 1980, the Norfolk Public Works Center (PWC)'s hazardous waste disposal division, has been accepting 1,000 to 1,500 gallons of hazardous waste per day. Norfolk PWC is responsible for collecting, packaging, and labelling hazardous materials before transferring them to the DPDO warehouse. According to Norfolk PWC, 477,000 gallons of hazardous waste were handled in 1983. It was recently estimated that half of this waste was virgin material with an expired shelf-life. Approximately

transferred, donated or sold, the paint would need to be disposed of as a hazardous waste due to its lead content. A contractor would then be responsible for recycling, selling, or safely disposing of the 100 cases of paint. It currently takes approximately one year from the time at which an item is listed on the EPL until the time it is disposed of as a hazardous waste. DLA is trying to reduce this time lag to 4 months.

11.2 Magnitude of Problem

It is believed that expired shelf-life items constitute a significant percentage of the hazardous wastes produced by the military. Almost all Army, Navy, and Air Force facilities dispose of expired shelf-life items. The exact quantities of expired shelf-life material handled by the DPDO is not known. DPDO records do not currently differentiate between expired shelf-life items and other wastes. The total cost of disposing and replacing the material has not been quantified. However, it can be surmised that modifications to the expired shelf-life program would result in substantial savings, and reduce potentially adverse future environmental impacts and liabilities.

11.3 Proposed Modifications

Various Navy personnel have recommended relaxing overly restrictive purchase and use specifications for shelf-life items to reduce the quantities of hazardous waste generated.

Item managers generally ship new stocks of material to Supply Centers based on prior use rather than current needs, resulting in significant overstocking. Therefore, large quantities of materials cannot be used before their shelf-life expires and eventually must be disposed of as hazardous wastes. This problem can be aggravated by successful hazardous waste management programs (e.g., solvent recycle and reuse), unless the line item manager reduced shipments to account for reduced need for new materials.

Navy products are usually required to meet stringent quality standards under the Military Specification (MILSPEC) Program. Expired shelf-life materials have been discarded because the items supposedly no longer met the MILSPEC standard. In many cases, the quality of shelf-life items (e.g., motor oil, paint, grease, and some solvents) does not degrade with time. Many of these unused materials are being donated to local and state governments for use. Other materials are being bought by contractors, repackaged, and sold back to the federal government.

Many shelf-life dates are based on the expected life of the container rather than of the contents. However, even if a

EVALUATION RESULTS (1)

CASE NO.	FACILITY, MODIFICATION	CRITERIA (1)					STUDY VALUE	(2)	NOTES (3)	(4)	REPORT SECTION
		A	B	C	D	E					
1	Hill AFB, Dry Paint Stripping	1.0	1.0	1.0	1.0	1.0	10.0	S		*	3.4.1
4	Robins AFB, Solvent Recycle	1.0	1.0	1.0	1.0	1.0	10.0	S		*	6.4.1
10	Pensacola NARF, Spray Rinse	1.0	1.0	1.0	1.0	1.0	10.0	S		*	5.4.4
26	Pensacola NARF, Dry Paint Strip	1.0	1.0	1.0	1.0	1.0	10.0	S		*	3.4.3
5	Tyndall AFB, Solvent Recycle	0.7	1.0	1.0	1.0	1.0	9.4	U b		*	6.4.2
18	Anniston Army Depot, Plating	1.0	1.0	0.7	1.0	1.0	9.4	S		*	5.4.7
8	Norfolk NSY, Solvent Recycle	1.0	0.5	1.0	1.0	1.0	9.0	S		*	6.4.4
24	Kelly AFB, Solvent Recycle	0.5	1.0	1.0	1.0	1.0	9.0	N g		*	6.4.5
7	Norfolk NARF, Heptane Recycle	1.0	0.7	0.7	1.0	1.0	8.8	U a, c		*	6.4.3
22	Alameda NARF, Dry Paint Strip	0.3	1.0	1.0	1.0	1.0	8.6	N k		*	3.4.2
23	Watervliet Army Arsenal, Modern Plating	0.5	1.0	1.0	1.0	0.7	8.4	S		*	5.4.10
6	Lockheed(USAF), CD Plating	1.0	0.5	0.7	1.0	1.0	8.4	S		*	5.4.1
16	Tobyhanna AAP, Waste Treatment	1.0	0.5	0.7	1.0	1.0	8.4	S		*	5.4.6
27	Pensacola NARF, Water Primer	1.0	0.5	0.7	1.0	1.0	8.4	S		*	4.4.3
39	Anniston Army Depot, Solvent Recycle	1.0	0.5	0.7	1.0	1.0	8.4	S		*	6.4.9
33	NARF's IVD of Aluminum	1.0	0.7	0.7	1.0	0.7	8.2	S		*	5.4.13
2	Hughes (USAF), Powder Coating	1.0	0.5	0.5	1.0	1.0	8.0	S		*	4.4.1
3	Lockheed (USAF), Painting	0.7	0.3	1.0	1.0	1.0	8.0	U a		*	4.4.2
40	Norfolk NSY and NARF, Shelf Life	0.5	1.0	1.0	0.5	1.0	8.0	U b		*	11.4.1
12	Charleston NSY, LICON Unit	1.0	0.5	0.7	1.0	0.7	7.8	U c, d, e, f		*	5.4.3
9	Pensacola NARF, LICON Unit	1.0	0.5	0.7	1.0	0.7	7.8	U c, d, e, f		*	5.4.2
14	Radford AAP, Pink Water	1.0	0.7	0.5	1.0	0.3	7.0	S		*	7.4.3
29	Pensacola NARF, Solvent Recycle	0.3	0.5	0.7	1.0	1.0	7.0	U m		*	6.4.6
34	Navy, Electrostatic Paint	0.5	0.5	0.5	1.0	0.7	6.4	U e		*	4.4.3
30	Pensacola NARF, Machine Coolant	1.0	0.3	0.3	1.0	0.5	6.2	U e, l		*	6.4.10
13	Radford AAP, NO _x Control	1.0	1.0	0.5	0.0	0.3	5.6	U d, h		*	7.4.1
15	Milan AAP, Pink Water	0.7	0.5	0.3	1.0	0.3	5.6	S		*	7.4.4
20	Alameda NARF, Rinse Controls	0.3	0.5	0.3	1.0	0.7	5.6	U e, j		*	5.4.9
25	Holston AAP, NO _x Treatment	1.0	1.0	0.5	0.0	0.3	5.6	U d, h		*	7.4.2
38	Navy, Fuel Tank Cleaning	0.5	0.5	0.5	0.3	1.0	5.6	U e		*	10.4.1
28	Pensacola NARF, Epoxy Paint	0.3	0.5	0.3	1.0	0.5	5.2	U f, d		*	4.4.3
31	Mare Island NSY, Plating	0.3	0.5	0.3	1.0	0.5	5.2	S		*	5.4.11
19	Alameda NARF, CN Rinse Changes	1.0	0.0	0.0	1.0	0.3	4.6	S		*	5.4.8
35	NAS's Fire Fighting	1.0	0.3	0.3	0.0	0.7	4.6	S		*	9.4.1
36	Charleston NSY, Refrigerant	1.0	0.5	0.3	0.0	0.3	4.2	S		*	6.4.7
17	Anniston Army Depot, Wet Paint Strip	0.0	0.0	0.0	1.0	1.0	4.0	N i		*	3.4.4
21	NARF Dry Jet Engine Test	1.0	0.0	0.3	0.0	0.5	3.6	S		*	8.4.1
32	NARF's Water Over MeCl ₂	0.0	0.0	0.0	1.0	0.5	3.0	N i		*	5.4.12
37	Norfolk NSY, Refrigerant Recycle	0.3	0.5	0.3	0.0	0.3	2.8	U c		*	6.4.8
11	Pensacola NARF, Cond. Recovery	0.5	0.0	0.0	0.0	0.5	2.0	N g		*	5.4.5

FOOTNOTES TO TABLE 13.1

(1) Key to evaluation of modifications

Each modification was assigned a score for each of the five criteria applied in evaluating a given modification. The criteria applied, and the five scores possible for each criteria, are shown below. The total score was then doubled to come up with the study value assigned.

Criteria	Weighting Value				
	1.0	0.7	0.5	0.3	0.0
A Concrete Example	Yes		Questionable		No
B Waste Reduction	Major		Moderate		Minor
C Waste Generation	Major		Moderate		Minor
D EPA Hazwaste	Yes		Sometimes		No
E Potential Use	Widespread		Limited		Unique

(2) S Process modification was judged successful in that it accomplished its goal, was cost-effective and sustainable.

U Process modification was judged not successful for reasons delineated under "Notes".

N Process modification was not yet implemented, or there was not sufficient information available to evaluate the modification.

(3) NOTES (Reasons for Lack of Success)

- a Negative impact on product quality.
- b Lack of authority by those attempting to implement the modification.
- c Lack of manpower.
- d Poor reliability or maintainability.
- e Inappropriate technology application.
- f Required skilled operators.
- g Process evaluation in progress, insufficient information.
- h Process consumables no longer commercially available.
- i No process modification was known to have been proposed.
- j Lack of space to locate the required equipment.
- k Not implemented, pending demonstration results at other facilities.
- l Physical properties of the material to be recycled kept changing.
- m Operation was discontinued due to lack of technical support and incentives to reduce hazardous wastes.

(4) * Recommended for additional study during Phase 2 of the project based on study value and availability of information to evaluate.

TABLE 13.1

EVALUATION OF
CASE STUDIES

CHM HILL

END

FILMED

9-85

DTIC